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Vol. I

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
PETITIONER,

vs.

RADIO CORPORATION OF AMERICA

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT

PETITION FOR CERTIORARI FILED JUNE 7, 1938.

CERTIORARI GRANTED OCTOBER 24, 1938.

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, 1938

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ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT

VOL. I

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[fol. 1]

IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

In Equity. No. 7234

RADIO CORPORATION OF AMERICA, Plaintiff,

vs.

MACKAY RADIO AND TELEGRAPH COMPANY, INC., Defendant

On Carter Patents Nos. 1,623,996 and 1,909,610, and Lindenblad Patents Nos. 1,884,006 and 1,927,522

BILL OF COMPLAINT

To the Honorable the Judges of the United States District Court for the Eastern District of New York:

The plaintiff, by this, its bill of complaint, alleges as follows:

1. That the plaintiff, Radio Corporation of America, is a corporation duly organized and existing under and by virtue of the laws of the State of Delaware; and, upon information and belief, that the defendant, Mackay Radio and Telegraph Company, Inc., is a corporation duly organized and existing under and by virtue of the laws of the State of Delaware, and that it has a regular and established place of business in the County of Suffolk, State of New York, in the Eastern District of New York, and has committed, is now committing, and threatens to continue to commit acts of infringement of each of the Letters Patent here in suit within said Eastern District of New York.

[fol. 2] 2. That this is a suit in equity arising under the Patent Laws of the United States for the infringement by the defendant of the following United States Letters Patent, viz:

Inventor	Patent No.	Date of Grant
Philip S. Carter	1,623,996	April 12, 1927.
Nils E. Lindenblad	1,884,006	October 25, 1932.
Nils E. Lindenblad	1,927,522	September 19, 1933.
Philip Staats Carter	1,909,610	May 16, 1933.

3. Upon information and belief, that Philip S. Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in a "Radio Transmission System", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about June 12, 1923, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office June 25, 1923, duly sell and assign to the plaintiff, Radio Corporation of America, its successor and assigns, the said improvements, [fol. 3] and the next hereinafter mentioned application for Letters Patent of the United States therefor and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

4. That on or about June 25, 1923, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Philip S. Carter.

5. That on or about February 12, 1925 an application in writing was duly made and filed with the Commissioner of Patents of the United States renewing the application referred to in paragraph 4 hereof, the invention thereof not having been abandoned.

6. That Letters Patent numbered 1,623,996 were, on April 12, 1927, duly issued upon the aforesaid application filed June 25, 1923, as renewed by said application filed February 12, 1925, all the provisions and requirements of the statutes of the United States in such cases made and provided hav-

ing been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

[fol. 4] 7. Upon information and belief, that Nils E. Lindenblad, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about August 31, 1928, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office September 7, 1928, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States, and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

8. That on or about September 7, 1928, an application in writing for the grant of Letters Patent upon said invention [fol. 5] or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Nils E. Lindenblad.

9. That Letters Patent numbered 1,884,006 were, on October 25, 1932, duly issued upon the aforesaid application

filed September 7, 1928, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

10. Upon information and belief, that Nils E. Lindenblad, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna for Radio Communication", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or [fol. 6] assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about December 17, 1928, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office December 24, 1928, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

11. That on or about December 24, 1928, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Nils E. Lindenblad.

12. That Letters Patent numbered 1,927,522 were, on September 19, 1933, duly issued upon the aforesaid application filed December 24, 1928, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or [fol. 7] discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

13. Upon information and belief, that Philip Staats Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Electric Circuit", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about March 6, 1930, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office March 12, 1930, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as assignee of the entire interest.

[fol. 8] 14. That on or about March 12, 1930, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and

filed with the Commissioner of Patents of the United States on behalf of said Philip Staats Carter.

15. That Letters Patent numbered 1,909,610 were, on May 16, 1933, duly issued upon the aforesaid application filed March 12, 1930, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein throughout the United States and the Territories thereof.

16. That the plaintiff has been ever since the grant of each of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, respectively, and now is, the sole and exclusive owner of each of them and of all claims for profits and damages for past infringement thereof.

17. That the plaintiff asks that the aforesaid assignments and Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, be deemed and taken as a part of this bill of complaint, and asks leave to refer to the originals of the same or duly authenticated copies thereof, now in their possession and ready in Court to be produced.

[fol. 9] 18. That the plaintiff and one or more of its licensees have expended large sums of money in making the inventions, discoveries and improvements of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, useful to the public and themselves; that the same have been practiced, and are now being practiced, by one or more of the licensees of the plaintiff; that the same have been and are of great value, importance, benefit and advantage to the plaintiff and its licensees and to the public; and that the same are capable of conjoint use, in one and the same structure and system, and have been and are being so used by the defendant.

19. That prior to the commencement of this suit, the defendant was duly notified of its infringement of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, and of each of them, and, as plaintiff is informed and be-

lieves, the defendant continued, after such notice, to use the inventions of each of said Letters Patent.

20. Upon information and belief, that since the dates of issuance of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, respectively, and within six years last past, and without right, license or consent of the plaintiff, and within the Eastern District of New York and elsewhere within the United States, the defendant, Mackay Radio & Telegraph Company, Inc., has made, installed, used and caused to be used devices, apparatus, structures, methods, and systems embodying and employing the respective inventions, discoveries, and improvements of each of said Letters Patent and infringement of each of them, and [fol. 10] also material and substantial parts of the inventions, discoveries and improvements of each of said Letters Patent, and now is continuing and threatening to continue to commit said acts of infringement.

21. Upon information and belief, that the defendant has derived and received and will derive and receive from the aforesaid infringement gains, profits, and advantages, but to what amount the plaintiff is not informed and cannot set forth; that the plaintiff and its licensees, by reason of the said infringement by the defendant, have been and will be deprived of and prevented from receiving, if such infringement is not restrained by this Court, gains, profits and advantages to which the plaintiff and its licensees are lawfully entitled and which they would have derived and received and would now be deriving and receiving but for the aforementioned infringement; that by reason of the aforesaid infringement the plaintiff and its licensees have been irreparably injured and have sustained losses and damages thereby; that the said infringement by the defendant has had and will have the effect of encouraging and inducing others to venture to infringe upon said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, and each of them; and that, unless the said infringement by the defendant is enjoined by this Court, further irreparable injury, loss and damage will be caused to the plaintiff and its licensees.

The plaintiff therefore prays:

I. That the defendant, Mackay Radio & Telegraph Company, Inc., and its directors, officers, associates, attorneys,

[fol. 11] clerks, servants, agents, workmen and employees, be perpetually enjoined and restrained by a decree of this Court from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use and lease, or causing to be advertised or offered for sale, use and lease, agreeing or contracting to sell and lease, causing to be agreed or contracted for sale and lease, supplying or causing to be supplied, installing or causing to be installed, threatening to offer or contract for sale, lease, and supply, or disposing of in any manner, devices, instruments, appliances, apparatus, structures, methods, or systems employing or employing the respective inventions or discoveries or improvements of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, or of any of them, or any substantial, material, or vital part or parts of said Letters Patent or of any of them, and from infringing upon or contributing to the infringement of, or encouraging, inducing or aiding the infringement of said Letters Patent or of any of them in any way whatsoever.

II. That a preliminary injunction issue against said defendant to the same tenor and effect as hereinbefore prayed for in respect to said perpetual injunction.

III. That said defendant be decreed to account to the plaintiff for all such gains, profits and advantages as have accrued to or have been earned or received by said defendant and also for all damages the plaintiff has sustained by [fol. 12] said infringement, and that the Court assess the same, or cause them to be assessed under its direction and increase the same as provided by law.

IV. That the said defendant be decreed to pay the costs, charges, and disbursements of this suit, and that the plaintiff have such other and further relief as the premises and the equity of the case may require and to the Court may seem just.

Radio Corporation of America, by Otto S. Schairer, Its Vice-President. Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., Of Counsel for Plaintiff.

[fol. 13] *Duly sworn to by Otto S. Schairer. Jurat omitted in printing.*

[fol. 14] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ANSWER

The defendant, for answer to the bill of complaint herein, or to as much thereof as it is advised is necessary or material to be answered, on information and belief says:

1. Answering paragraph 1 of the bill of complaint defendant denies that it has infringed the patents involved in the suit in the Eastern District of New York or elsewhere.

2. Defendant denies each and every allegation contained in paragraphs 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 of the bill of complaint, except that it admits having seen what purported to be printed copies of Carter patents Nos. 1,623, 999 and 1,909,610, and Lindenblad patents Nos. 1,884-006 and 1,927,522 granted on the dates appearing thereon on applications filed on the dates recited therein.

3. For answer to paragraph 16 of the bill of complaint defendant is without information, save that obtained from the [fol. 15] bill of complaint, and from the said printed copies of the said patents, and therefore leaves plaintiff to its proofs.

4. Defendant denies each and every allegation contained in paragraphs 18, 19, 20, and 21 of the bill of complaint.

5. Further answering the bill of complaint, defendant affirmatively asserts that it does not infringe said Letters Patent or anyone thereof.

6. Further answering the bill of complaint defendant asserts that the said Letters Patent, and each thereof, are wholly void and invalid at law for each of the following reasons, to wit:

(a) Because the alleged invention of said Letters Patent, and each thereof, was shown and/or described in printed publications of the United States and countries foreign to the United States before the alleged invention by the respective patentees, and more than two years prior to the

filing of application for patent on which said respective patents issued, as follows:

(1) As to Carter Patent No. 1,623,996—

United States Patents

No.	Inventor	Issue Date
712,766	Colpitts	Nov. 4, 1902
729,709	Warren-Campbell	June 21, 1903
730,246	DeForest	June 9, 1903
730,247	DeForest	June 9, 1903
730,819	DeForest	June 9, 1903
773,472	Campbell	Oct. 25, 1904
874,411	LeBlanc	Dec. 24, 1907
956,165	Pickard	Apr. 26, 1910
961,265	Stone	June 14, 1910
1,013,456	Seibt	Dec. 19, 1911

[fol. 16]

1,124,904	Hoyt	Jan. 12, 1915
1,129,959	Colpitts	Mar. 2, 1915
1,167,693	Hoyt	Jan. 11, 1916
1,219,760	Mills-Hoyt	Mar. 20, 1917
1,243,066	Hoyt	Oct. 16, 1917
1,301,644	Buckley	Apr. 22, 1919
1,313,483	Heising	Aug. 19, 1919
1,322,634	Shaw	Nov. 25, 1919
1,333,111	Hoyt	Mar. 9, 1920
1,367,590	Demarest	Feb. 8, 1921
1,381,089	Beverage	June 7, 1921
1,430,808	Hoyt	Oct. 3, 1922
1,452,849	Round	Apr. 24, 1923

British Patent

4277/1873

Publications

Electrical Papers, Vol. 2, by Heaviside, pp. 124-155—"Electromagnetic Induction and Its Propagation"; published 1892 by MacMillan Company.

Electrical World & Engineer, Vol. 38, No. 19, November 9, 1901, pp. 775-776—"Slaby-D'Arco Multiple Wireless System".

The Electrical World, Vol. 48, No. 21, November 24, 1906—"The Carborundum Wireless Detector".

Electric Waves, published October, 1909, by MacMillan Company, New York, W. S. Franklin, Chaps. IV and V, pp. 75-153.

Proceedings I. R. E., Vol. 31, Part I, May 17, 1912—"Propagation of Impulses over a Transmission Line" by Cunningham and Davis.

[fol. 17] The Wireless World, Vol. 1, November, 1913—"Electromagnetic Waves Employed in Radio-Telegraphy" by Howe, pp. 486-492.

The Wireless World, Vol. 1, December, 1913—"The Use of High Resistance Telephones", pp. 580-581.

Transactions of A. I. E. E., Vol. 33, April, 1914—"Some Simple Examples of Transmission Line Surges" by W. S. Franklin, pp. 545-569.

(a) As to Carter Patent No. 1,909,610—

United States Patents

No.	Inventor	Issue Date
712,766	Colpitts	Nov. 4, 1902
729,709	Warren-Campbell	June 21, 1903
730,246	DeForest	June 9, 1903
730,247	DeForest	June 9, 1903
730,819	DeForest	June 9, 1903
773,472	Campbell	Oct. 25, 1904
874,411	LeBlanc	Dec. 24, 1907
956,165	Pickard	Apr. 26, 1910
961,265	Stone	June 14, 1910
1,012,456	Seibt	Dec. 19, 1911
1,124,904	Hoyt	Jan. 12, 1915
1,129,959	Colpitts	Mar. 2, 1915
1,167,693	Hoyt	Jan. 11, 1916
1,219,760	Mills-Hoyt	Mar. 20, 1917
1,243,066	Hoyt	Oct. 16, 1917
1,301,644	Buckley	Apr. 22, 1919
1,313,483	Heising	Aug. 19, 1919
1,322,634	Shaw	Nov. 25, 1919
1,333,111	Hoyt	Mar. 9, 1920
1,367,590	Demarest	Feb. 8, 1921
1,381,089	Beverage	June 7, 1921
1,430,808	Hoyt	Oct. 3, 1922
1,452,849	Round	Apr. 24, 1923
1,475,997	Hoyt	Dec. 4, 1923
1,487,308	Beverage	Mar. 18, 1924
1,495,221	Clark	May 27, 1924
1,537,101	Whiting	May 12, 1925

[fol. 18]

No.	Inventor	Issue Date
1,562,961	Heising	Nov. 24, 1925
1,585,018	Casper-Whittle	May 18, 1926
1,601,023	Hoyt	Sept. 28, 1926
1,602,085	Rice-Kellogg	Oct. 5, 1926
1,602,086	Rice-Kellogg	Oct. 5, 1926
1,623,996	Carter	Apr. 12, 1927
1,628,983	Johnson	May 17, 1927
1,647,985	Deutschmann	Nov. 8, 1927
1,676,240	Affel	July 10, 1928
1,689,334	Feldtkeller	Oct. 30, 1928
1,690,233	Kupfmuller	Nov. 6, 1928
1,691,098	Whiting	Nov. 13, 1928

Publications

Electrical Papers, Vol. 2, by Heaviside, pp. 124-155—"Electromagnetic Induction and Its Propagation", published 1892 by MacMillan Company.

Electrical World & Engineer, Vol. 38, No. 19, November 9, 1901, pp. 775-776—"Slaby D'Arco Multiple Wireless System".

The Electrical World, Vol. 48, No. 21, November 24, 1906—"The Carborundum Wireless Detector", by Pickard, pp. 994-995.

Electric Waves, published October, 1909, by MacMillan Co., New York, W. S. Franklin, Chaps. IV and V, pp. 75-153.

Proceedings I. R. E., Vol. 31, Part I, May 17, 1912—"Propagation of Impulses Over a Transmission Line", by Cunningham and Davis.

The Wireless World, Vol. 1, November, 1913—"Electromagnetic Waves Employed in Radio-Telegraphy", by Howe, pp. 486-492.

[fol. 19] The Wireless World, Vol. 1, December, 1913—"The Use of High Resistance Telephones", pp. 580-581.

Transactions of A. I. E. E., Vol. 33, April, 1914—"Some Simple Examples of Transmission Line Surges", by W. S. Franklin, pp. 545-569.

Transmission Circuits for Telephonic Communication, published 1925 by Van Nostrand—K. S. Johnson—Chaps. VII and VIII, pp. 43-85.

British Patents

4277/1873
282905/1927

(3) As to Lindenblad Patent No. 1,884,006—

United States Patents

No.	Inventor	Issue Date
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
808,594	Artom	Dec. 26, 1905
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,116,588	Harrison	Nov. 10, 1914
1,360,167	Alexanderson	Nov. 23, 1920
Re-15,040	Franklin	Feb. 15, 1921
Re-15,041	Franklin	Feb. 15, 1921
1,370,735	Franklin	Mar. 8, 1921
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928

British Patents

11,427/1903
233,346/1926
251,638/1927

[fol. 20] French Patents

593,570, Published Aug. 26, 1925;
Add. 30,798, Published Aug. 23, 1926.

Publications

Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

The Electrician, December 18, 1914—"The Possibility of Sharp Direction Wireless Telegraphy", by Bellini, pp. 352-354.

Proceedings of Physical Society of London, Vol. 29, 1917—"Radiation from Antennae", by Van der Pol, pp. 269-289.

Proceedings I. R. E., Vol. 12, October, 1924—"On the Optimum Transmitting Wave Length for a Vertical

Antenna Over Perfect Earth", by Stuart Ballantine, pp. 833-839.

"On the Radiation Resistance of a Simple Vertical Antenna at Wavelengths Below the Fundamental", by Stuart Ballantine, pp. 823-832.

Proceedings I. R. E., Vol. 13, April, 1925—Discussion re above, pp. 251-255.

Q. S. T., August, 1926—"Straightening Out the Antenna", by Melton, pp. 30-32.

Proceedings I. R. E., Vol. 14, October, 1926—"Field Distribution and Radiation Resistance of a Straight Vertical Unloaded Antenna Radiating at One of Its Harmonics", by Levin and Young, pp. 675-688.

[fol. 21] Proceedings I. R. E., Vol. 15, May, 1927—Discussion re above, pp. 439-443.

Proceedings I. R. E., Vol. 15, May, 1927—"High Angle Radiation of Short Electric Waves", by Uda, pp. 377,383.

(4) As to Lindenblad Patent No. 1,927,522—

United States Patents

No.	Inventor	Issue Date
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
794,334	Artom	July 11, 1905
795,762	Garcia	July 25, 1905
808,594	Artom	Dec. 26, 1905
918,255	Athearn	Apr. 13, 1909
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,116,588	Harrison	Nov. 10, 1914
1,147,010	Fessenden	July 20, 1915
1,353,735	Espenschied	Sept. 21, 1920
1,360,167	Alexanderson	Nov. 23, 1920
Re-15,040	Franklin	Feb. 15, 1921
Re-15,041	Franklin	Feb. 15, 1921
1,370,735	Franklin	Mar. 8, 1921
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928
1,683,739	Stone	Sept. 11, 1928

British Patents

11,427/1903
223,742/1924
233,346/1926
251,638/1927

French Patents

593,570, Published Aug. 26, 1925;
Add. 30,798, Published Aug. 23, 1926.

Publications

[fol. 22] Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

The Electrician, December 18, 1914—"The Possibility of Sharp Direction Wireless Telegraphy", by Bellini, pp. 352-354.

Proceedings of Physical Society of London, Vol. 29, 1917, "Radiation from Antennae", Van der Pol, pp. 269-289.

The Wireless Age, September, 1921, pp. 36-37—"Better Antennas", by D. W. Richardson.

Proceedings I. R. E., Vol. 12, October, 1924—"On the Optimum Transmitting Wave Length for a Vertical Antenna at Wavelengths Below the Fundamental", by Stuart Ballantine, pp. 823-832.

Proceedings I. R. E., Vol. 13, April, 1925—Discussion re above, pp. 251-255.

Q. S. T., August, 1926—"Straightening Out the Antenna", by Melton, pp. 30-32.

Proceedings I. R. E., Vol. 14, October, 1926—"Field Distribution and Radiation Resistance of a Straight Vertical Unloaded Antenna Radiating at One of Its Harmonics", by Levin and Young, pp. 675-688.

Proceedings I. R. E., Vol. 15, May, 1927—Discussion re above, pp. 439-443.

[fol. 23] Proceedings I. R. E., Vol. 15, May, 1927—"High Angle Radiation of Short Electric Waves", by Uda, pp. 377-383.

(b) Because said patents, and each thereof, disclose no patentable invention over and in view of the state of the

art at and prior to the time application for patent on each of said patents was filed and as illustrated by the instances thereof referred to in paragraph (a) hereof.

(c) Because the invention claimed in the original of each of said patents is substantially different from any indicated, suggested, or described in the original application therefor.

(d) Because the patentee of each of said patents surreptitiously or unjustly obtained the patent for that which was in fact the invention of another who was using reasonable diligence in adapting and perfecting the same. Instances thereof are as follows:

(1) As to Carter Patent No. 1,623,996—

United States Patents

No.	Inventor	Issue Date
1,475,997	Hoyt	Dec. 4, 1923
1,487,308	Beverage	Mar. 18, 1924
1,495,221	Clark	May 27, 1924
1,537,101	Whiting	May 12, 1925
1,562,961	Heising	Nov. 24, 1925
1,602,085	Rice-Kellogg	Oct. 5, 1926
1,602,086	Rice-Kellogg	Oct. 5, 1926
1,676,240	Affel	July 10, 1928
1,690,233	Kupfmuller	Nov. 6, 1928

[fol. 24] (2) As to Carter Patent No. 1,909,610—

United States Patents

No.	Inventor	Issue Date
1,778,395	Lindenblad	Oct. 14, 1930
1,868,795	Hansell	July 26, 1932
1,874,966	Green	Aug. 30, 1932
1,893,136	Franklin-Green	Jan. 3, 1933
1,898,180	Hansell	Feb. 21, 1933
1,901,025	Franklin	Mar. 14, 1933

(3) As to Lindenblad Patent No. 1,884,006—

United States Patents

No.	Inventor	Issue Date
1,683,739	Stone	Sept. 11, 1928
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,740,371	Rice	Dec. 17, 1929
1,759,000	Chapman	May 20, 1930
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,402	Peterson	Sept. 1, 1931
1,821,936	Franklin	Sept. 8, 1931

(4) As to Lindenblad Patent No. 1,927,522—

United States Patents

No.	Inventor	Issue Date
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,740,371	Rice	Dec. 17, 1929
1,759,000	Chapman	May 20, 1930
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,402	Peterson	Sept. 1, 1931
1,821,936	Franklin	Sept. 8, 1931
1,738,459	Stanley	Dec. 3, 1929

[fol. 25] (e) Because for the purpose of deceiving the public the description and specification filed in the Patent Office in each of the said cases was made to cover less than the whole truth relevant to the invention, or was made to cover more than was necessary to produce the desired effect.

(f) Because the description of the invention in the specification of each of said patents is not in such full, clear, concise, and exact terms as to enable any person skilled in the art or science to which it pertains or with which it is most nearly connected to make, construct, compound, and use the same.

(g) Because the invention of each of said patents was known to others and/or in public use and/or on sale before the alleged invention by each of the said patentees, or more than two years prior to the filing of application for Letters Patent therefor.

7. Further answering the bill of complaint defendant asserts that plaintiff comes to this Court of equity with unclean hands and is barred by principles of equity and by estoppel from equitable relief.

8. Further answering the bill of complaint defendant asserts that plaintiff is debarred from the relief prayed for, or to any equitable relief, by reason of its laches in asserting its claims as against this defendant with respect to said Letters Patent, and each thereof.

[fol. 26] Wherefore defendant denies that plaintiff is entitled to the relief prayed for, or to any relief, and there-

fore prays to be hence dismissed with its costs in this cause sustained, and for such other and further relief as to the Court may seem just.

Mackay Radio & Telegraph Company, Inc., by Samuel E. Darby, Jr., Its Attorney. Darby & Darby, Attorneys for Defendant, #405 Lexington Avenue, New York City, N. Y. Hugh M. Morris, Samuel E. Darby, Jr., of Counsel.

Dated, New York, N. Y., May 15, 1934.

[fol. 27] In United States District Court, Eastern District of New York

[Title omitted]

Motion for Leave to File Supplemental Bill

Now comes Radio Corporation of America, the plaintiff in the above entitled cause, by Sheffield & Betts, its solicitors, and moves this Court for an order granting leave to plaintiff to file herein the annexed supplemental bill of complaint and for such other and further relief as may seem to the Court to be just and proper.

Dated, New York, October 4, 1934.

Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., of Counsel.

[fol. 28] In United States District Court, Eastern District of New York

[Title omitted]

Order Allowing Supplemental Bill

Upon the pleadings and proceedings heretofore had herein and upon the annexed motion of plaintiff for an order granting plaintiff leave to file the annexed supplemental bill of complaint, the defendant not opposing said motion, it is hereby

Ordered that the said motion of plaintiff be and the same hereby is granted and that leave be and hereby is granted

to plaintiff to file herein the annexed supplemental bill of complaint.

Dated Oct. 5, 1934.

Mortimer W. Byers, U. S. D. J.

Defendant not opposing plaintiff's motion hereinabove referred to, entry of the foregoing order without further notice is hereby consented to.

Darby & Darby, Solicitors for Defendant.

[fol. 29] IN UNITED STATES DISTRICT COURT

[Title omitted]

SUPPLEMENTAL BILL OF COMPLAINT

To the Honorable the Judges of the United States District Court for the Eastern District of New York:

The plaintiff, by this, its supplemental bill of complaint, alleges as follows:

1. That on or about April 21, 1934, plaintiff filed its original bill of complaint for the infringement by defendant of United States Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610; that on or about May 15, 1934, defendant duly appeared herein and filed its answer to said original bill; and that other proceedings have duly been had herein.

2. That defendant has a regular and established place of business in the County of Suffolk, State of New York, in the Eastern District of New York, and has committed, is now committing, and threatens to continue to commit acts of infringement of United States Letters Patent No. 1,974,387 hereinafter mentioned, within said Eastern District of New York.

[fol. 30] 3. Upon information and belief, that Philip S. Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or

more than two years prior to his application for Letters Patent in the United States, hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about June 5, 1930, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office June 11, 1930, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the hereinafter mentioned application for Letters Patent of the United States therefor and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

4. That on or about June 11, 1930, an application in writing for the grant of Letters Patent upon said invention or [fol. 31] discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Philip S. Carter.

5. That Letters Patent numbered 1,974,387 were, on September 18, 1934, duly issued upon the aforesaid application, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and then for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

6. That the plaintiff has been ever since the grant of said Letters Patent No. 1,974,387, and now is, the sole and exclusive owner thereof and of all claims for profits and damages for past infringement thereof.

7. That the plaintiff asks that the aforesaid assignment and Letters Patent No. 1,974,387 be deemed and taken as

a part of this bill of complaint, and asks leave to refer to the originals of the same or duly authenticated copies thereof, now in its possession and ready in Court to be produced.

8. That the plaintiff and one or more of its licensees have [fol. 32] expended large sums of money in making the inventions, discoveries and improvements of said Letters Patent No. 1,974,387 useful to the public and themselves; that the same have been practiced, and are now being practiced, by one or more of the licensees of the plaintiff; that the same have been and are of great value, importance, benefit and advantage to the plaintiff and its licensees and to the public; and that the invention, discovery, and improvements of said Letters Patent are capable of conjoint use with those of the said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, referred to in said original bill of complaint, in one and the same structure and system, and have been and are being so used by the defendant.

9. That prior to the execution of this supplemental bill of complaint, the defendant was duly notified of its infringement of said Letters Patent No. 1,974,387 and, as plaintiff is informed and believes, the defendant continued, after such notice, to use the invention of said Letters Patent.

10. Upon information and belief, that since the date of issuance of said Letters Patent No. 1,974,387 and without right, license or consent of the plaintiff, and within the Eastern District of New York and elsewhere within the United States, the defendant, Mackay Radio & Telegraph Company, Inc., has used and caused to be used devices, apparatus, structures, and systems embodying and employing the invention, discovery, and improvements of said Letters Patent and in infringement thereof, and also material and substantial parts of the invention, discovery and improvements of said Letters Patent, and now is continu- [fol. 33] ing and threatening to continue to commit said acts of infringement; and that some or all of the devices, apparatus, structures, and systems so complained of in this supplemental bill of complaint are also complained of in said original bill of complaint.

11. Upon information and belief, that the defendant has derived and received and will derive and receive from the

aforesaid infringement gains, profits, and advantages, but to what amount the plaintiff is not informed and cannot set forth; that the plaintiff and its licensees, by reason of the said infringement by the defendant, have been and will be deprived of and prevented from receiving, if such infringement is not restrained by this Court, gains, profits and advantages to which the plaintiff and its licensees are lawfully entitled and which they would have derived and received and would now be deriving and receiving but for the aforementioned infringement; that by reason of the aforesaid infringement the plaintiff and its licensees have been irreparably injured and have sustained losses and damages thereby; that the said infringement by the defendant has had and will have the effect of encouraging and inducing others to venture to infringe upon said Letters Patent No. 1,974,387; and that, unless the said infringement by the defendant is enjoined by this Court, further irreparable injury, loss and damage will be caused to the plaintiff and its licensees.

The plaintiff therefore prays:

I. That the defendant, Mackay Radio & Telegraph Company, Inc., and its directors, officers, associates, attorneys, [fol. 34] clerks, servants, agents, workmen and employees, be perpetually enjoined and restrained by a decree of this Court from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use and lease, or causing to be advertised or offered for sale, use and lease, agreeing or contracting to sell and lease, causing to be agreed or contracted for sale and lease, supplying or causing to be supplied, installing or causing to be installed, threatening to offer or contract for sale, lease, and supply, or disposing of in any manner, devices, instruments, appliances, apparatus, structures, or systems embodying or employing the invention or discovery or improvements of said Letters Patent No. 1,974,387 or any substantial, material, or vital part or parts of said Letters Patent, and from infringing upon or contributing to the infringement of, or encouraging, inducing or aiding the infringement of said Letters Patent in any way whatsoever.

II. That a preliminary injunction issue against said defendant to the same tenor and effect as hereinbefore prayed for in respect to said perpetual injunction.

III. That said defendant be decreed to account to the plaintiff for all such gains, profits and advantages as have accrued to or have been earned or received by said defendant and also for all damages the plaintiff has sustained by said infringement, and that the Court assess the same, or [fol. 35] cause them to be assessed under its direction and increase the same as provided by law.

IV. That the said defendant be decreed to pay the costs, charges, and disbursements of this suit.

V. That the parties hereto shall be allowed full benefit of all the pleadings and proceedings had herein.

VI. That the plaintiff have such other and further relief as the premises and the equity of the case may require and to the Court may seem just.

Radio Corporation of America, by Otto S. Schairer, Its Vice-President. Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., Of Counsel for Plaintiff.

[fol. 36] *Duly sworn to by Otto S. Schairer. Jurat omitted in printing.*

[fol. 37] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ANSWER TO SUPPLEMENTAL BILL OF COMPLAINT

The defendant, for answer to the supplemental bill of complaint herein, or to as much thereof as it is advised is necessary or material to be answered, on information and belief says:

1. Answering paragraph 2 of the supplemental bill of complaint, defendant denies that it has committed or threatens to commit acts of infringement of Letters Patent No.

1,974,387, either in the Eastern District of New York or elsewhere.

2. Defendant denies each and every allegation contained in paragraphs 3, 4 and 5 of the supplemental bill of complaint, except that it admits having seen what purported to be a printed, uncertified copy of Patent No. 1,974,387 issued to plaintiff, Radio Corporation of America, its successors and assigns.

3. Defendant is uninformed, save by the supplemental bill of complaint, as to the matters alleged in paragraph [fol. 38] 6 thereof, and therefore leaves plaintiff to its proofs.

4. Defendant denies each and every allegation contained in paragraphs 8, 9, 10 and 11 of the supplemental bill of complaint.

5. Further answering the supplemental bill of complaint, defendant affirmatively asserts that it does not infringe said Letters Patent.

6. Further answering the supplemental bill of complaint, defendant asserts that said Letters Patent is wholly void and invalid at law for each of the following reasons, to wit:

(a) Because the alleged invention of said Letters Patent was shown and/or described in printed publications of the United States and countries foreign to the United States before the alleged invention of the said patentee, and/or more than two years prior to the filing of the application for patent on which the said patent issued as follows:

United States Patents

No.	Inventor	Issue Date
663,400	Wilson and Evans	Dec. 4, 1900
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
760,463	Marconi	May 24, 1904
794,334	Artom	July 11, 1905
795,762	Garcia	July 25, 1905
808,594	Artom	Dec. 26, 1905
924,560	Marconi	June 8, 1909
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,101,914	Fessenden	June 30, 1914
1,116,588	Harrison	Nov. 10, 1914
1,147,010	Fessenden	July 20, 1915

[fol. 39]

No.	Inventor	Issue Date
1,360,167	Alexanderson	Nov. 23, 1920
1,370,735	Franklin	Mar. 8, 1921
1,491,372	Alexanderson	Apr. 22, 1924
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928
1,683,739	Stone	Sept. 11, 1928
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,936	Franklin	Sept. 8, 1931
1,827,054	Von Arco	Oct. 13, 1931

Foreign Patents

British

11,427/1903
233,346/1926
251,638/1927
295,693/Jan. 31, 1929
299,447/Feb. 28, 1929

French

593,570 Published Aug. 26, 1925
Add. 30,798 Published Aug. 23, 1926

Publications

Widemann's Annalen der Physik, 1898, pp. 435-472—Abraham.

Physikalische Zeitschrift, March 2, 1901, pp. 329-334—Abraham.

Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

[fol. 40] The Electrician, March 8, 1912, pp. 868-870.

The Electrician, December 18, 1914, pp. 352-354.

Proceedings Physical Society of London, Vol. 29, 1917, pp. 269-289—Van der Pol.

Proceedings I. R. E., Vol. 12, October, 1924, pp. 833-839—Ballantine.

Proceedings I. R. E., Vol. 12, October, 1924, pp. 823-832—Ballantine.
Proceedings I. R. E., Vol. 13, April, 1925, pp. 251-255.
Q. S. T., August, 1926, pp. 30-32—"Straightening Out the Antenna."
Proceedings I. R. E., Vol. 14, October, 1926, pp. 675-688—Levin-Young.
Proceedings I. R. E., Vol. 15, May, 1927, pp. 439-443—Levin-Young.
Proceedings I. R. E., May, 1927, pp. 377-385—Uda.

(b) Because said patent discloses no patentable invention over and in view of the state of the art at and prior to the time the application for said patent was filed and as illustrated by the instances thereof referred to in paragraph (a) hereof.

(c) Because the invention claimed in said patent is substantially different from any indicated, suggested or described in the original application therefor.

(d) Because the patentee surreptitiously or unjustly obtained the patent for that which was in fact the invention of [fol. 41] another who was using reasonable diligence in adapting and perfecting the same. Instances thereof are as follows:

Lindenblad Patent No. 1,884,006, granted Oct. 25, 1932, on an application filed Sept. 7, 1928.

Bruce Patent No. 1,899,410, granted Feb. 28, 1933, on an application filed Oct. 11, 1929.

Lindenblad Patent No. 1,927,522, granted Sept. 19, 1933, on an application filed Dec. 24, 1928.

(e) Because for the purpose of deceiving the public the description and specification filed in the Patent Office as part of the application for said patent was made to cover less than the whole truth relevant to the invention, or more than was necessary to produce the desired effect.

(f) Because the description of the invention in the specification of said patent is not in such full, clear, concise and exact terms as to enable any person skilled in the art or science to which it pertains or with which it is most nearly connected to make, construct, compound and use the same.

(g) Because the invention of said patent was known to others and/or in public use and/or on sale before the al-

leged invention by the said patentee, or more than two years prior to the filing of application for Letters Patent therefor.

7. Further answering the supplemental bill of complaint, defendant asserts that plaintiff comes to this Court of [fol. 42] Equity with unclean hands and is barred by principles of equity and by estoppel from equitable relief.

Wherefore, defendant denies that plaintiff is entitled to the relief prayed for, or to any relief, and therefore prays to be hence dismissed with its costs in this cause sustained, and for such other and further relief as to the Court may seem just.

Mackay Radio and Telegraph Company, Inc., by Samuel E. Darby, Jr., Its Attorney. Darby & Darby, Attorneys for Defendant, #405 Lexington Avenue, New York City, N. Y. Hugh M. Morris, Samuel E. Darby, Jr., Of Counsel.

Dated, New York, N. Y., November 23, 1934.

[fol. 43] In United States District Court, Eastern District of New York

E 7234

Radio Corporation of America, Plaintiff,

vs.

Mackay Radio & Telegraph Co., Inc., Defendant

Before Hon. Marcus B. Campbell, U. S. D. J.

Statement of Evidence

Brooklyn, N. Y., January 2, 1935.

Appearances

Sheffield & Betts, Esqs., Solicitors for Plaintiff; Jo. Baily Brown, Esq., Abel E. Blackmar, Jr., Esq., and Harry Tunick, Esq., of Coursel.

Darby & Darby, Esqs., Solicitors for Defendant; Hon. Hugh M. Morris, Samuel E. Darby, Jr., Esq., and Paul Kolisch, Esq., of Counsel.

Mr. Blackmar: If your Honor please, I offer in evidence a copy of each of the five patents in suit, suggesting that they be marked in this order: First Carter patent No. 1,623,996.

(Marked Plaintiff's Exhibit 1 in evidence.)

[fol. 44] Mr. Blackmar: The second Carter patent No. 1,909,610.

(Marked Plaintiff's Exhibit 2 in evidence.)

Mr. Blackmar: Then the first Lindenblad patent No. 1,884,066.

(Marked Plaintiff's Exhibit 3 in evidence.)

Mr. Blackmar: Then the second Lindenblad patent No. 1,927,522.

(Marked Plaintiff's Exhibit 4 in evidence.)

Mr. Blackmar: Then the third Carter patent, 1,974,387.

(Marked Plaintiff's Exhibit 5 in evidence.)

Mr. Blackmar: I have a stipulation covering certain formal matters. The stipulation also covers notice, and may I ask Mr. Darby whether he will concede that these V type antennas were used by the defendant between the date of notice and the commencement of the suit?

Mr. Darby: Oh, surely.

Mr. Blackmar: And also as to the third Carter patent, between the date of that notice and the filing of the supplemental bill?

Mr. Darby: We will concede that we used it since; that will be sufficient for your purposes.

Mr. Blackmar: And any question as to accounting, if any, may be left until that time on that basis.

Mr. Darby: All right.

(The stipulation referred to is marked Plaintiff's Exhibit 6 in evidence and is as follows:)

[fol. 45] PLAINTIFF'S EXHIBIT 6

STIPULATION

"It is Hereby Stipulated and Agreed, solely for the purposes of this suit, by and between the solicitors for the respective parties hereto, as follows:

"1. That certified copies of such United States Letters Patent as the parties may desire to introduce in evidence at the trial of this cause, need not be furnished, but that the usual printed copies supplied by the United States Patent Office shall be sufficient proof of the issue of such Letters Patent and of the contents thereof, provided, however, that correction may be made should error appear, and provided further that such printed copies shall not be used as evidence of the dates of filing or of the contents of the applications on which the Letters Patent were granted.

"2. That certified or exemplified copies of such foreign Letters Patent as the parties may desire to introduce in evidence at the trial of this cause, need not be furnished, provided printed copies thereof are available, but that photostatic copies of such Letters Patent, such as are obtainable from the United States Patent Office or The New York Public Library may be offered in evidence and shall be sufficient proof of the issue of such Letters Patent and of the contents thereof and of the dates stated thereon, provided, however, that correction may be made should error appear.

"3. That photostatic copies of publications may be offered in evidence by either party with the full force [fol. 46] and effect of the originals thereof, and that such copies shall be sufficient proof of the publication thereof at the dates appearing thereon, provided, however, that either party, upon reasonable notice thereof to the other party, may question either the fact or date of publication of any of said publications and require the other party to make proof thereof, and that correction may be made should error appear.

"4. That the defendant, Mackay Radio & Telegraph Company, Inc., commenced the construction of its first 'V-type' antennas early in June, 1932, and first placed them in commercial operation early in July, 1932.

"5. That plaintiff notified the defendant, on or about April 20, 1934, that it considered that defendant was infringing the Letters Patent here in suit Nos. 1,623,996, 1,884,006, 1,909,610 and 1,927,522; and that plaintiff notified the defendant, on or about September 24, 1934, that it considered that defendant was infringing Letters Patent No. 1,974,387, here in suit.

"6. That the paper submitted herewith and entitled 'Description of Sayville Antenna No. 8' (taken together with the diagram annexed thereto entitled 'Exhibit A, WMZ-20 Antenna System') is a true and correct statement of the facts therein set forth (subject to correction should error appear). And that, similarly, the papers submitted herewith and entitled 'Description of Sayville Antenna No. 10', 'Description of Sayville Antenna No. 1', 'Description of Sayville Antenna No. 2', 'Description of Sayville Antenna [fol. 47] No. 11', and 'Description of Sayville Antenna No. 7' (taken together with the diagrams annexed thereto and respectively entitled 'Exhibit B, WKT Antenna System', 'Exhibit C, WIU Antenna System', 'Exhibit D, WML Antenna System', 'Exhibit E, WKS Antenna System', and 'Exhibit F, WSE Antenna System') are true and correct statements of the facts therein set forth (subject to correction should error appear). And that the dimensions and other data set forth on the two sheets marked 'Exhibit G—Tabulation of Dimensional Data for V-Antennas at Sayville' are true and correct (subject to correction should error appear).

Dated, New York, N. Y., December 4, 1935.

"Sheffield & Betts, Solicitors for Plaintiff. "Darby & Darby, Solicitors for Defendant."

Mr. Blackmar: I now offer in evidence the agreed description of the Sayville Antenna No. 8, together with a diagram thereof, which has been marked Exhibit A.

(Marked Plaintiff's Exhibit 7 in evidence.)

Mr. Blackmar: I also offer in evidence description and diagram marked Exhibit B, with respect to the Sayville Antenna No. 10.

(Marked Plaintiff's Exhibit 8 in evidence.)

Mr. Blackmar: I also offer in evidence the description and diagram marked Exhibit C of the Sayville Antenna No. 1.

(Marked Plaintiff's Exhibit 9 in evidence.)

[fol. 48] Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit D of the Sayville Antenna No. 2.

(Marked Plaintiff's Exhibit 10 in evidence.)

Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit E of the Sayville Antenna No. 11.

(Marked Plaintiff's Exhibit 11 in evidence.)

Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit F of the Sayville Antenna No. 7.

(Marked Plaintiff's Exhibit 12 in evidence.)

Mr. Blackmar: I also offer two sheets annexed to the stipulation, marked Exhibit G, constituting a tabulation of dimensional data.

(Marked Plaintiff's Exhibit 13 in evidence.)

CLARENCE W. HANSELL, called as a witness on behalf of the plaintiff, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I reside at Port Jefferson, New York, am a radio engineer, and am a graduate engineer also.

I have charge of the transmitter research and development laboratory of RCA Communications, Inc., at Rocky Point, Long Island. My understanding is that that com- [fol. 49] pany is a wholly-owned subsidiary of RCA, by which I mean the Radio Corporation of America; it is the Communications subsidiary of the parent company.

My first experience in radio communication was obtained in 1918 from a short course in the Student Training Corps of the United States Army at Purdue University. Then I graduated from Purdue University in June of 1919 and I was employed after that by the General Electric Company at Schenectady, New York.

In 1920, while I was working for the General Electric Company, I was put in charge of tests on the Alexanderson high frequency alternators which were being manufactured by the General Electric Company for installation in transoceanic stations of the Radio Corporation of America. By Alexanderson high frequency alternators, I mean the ma-

chines that generate the currents used for transmitting signals.

I was transferred to the Radio Corporation of America in September of 1920. I then became one of several assistants to Mr. E. F. W. Alexanderson, who was then chief engineer of the Radio Corporation of America, and under Mr. Alexanderson I worked on quite a large variety of research, development, and design problems connected with trans-oceanic and marine transmitting stations.

I assisted in the design of the station at Rocky Point. I am familiar, in a general way, in most respects, with the work of the Radio Corporation of America in the development of directive antennas for long distance short wave communications. According to my recollection, the Radio [fol. 50] Corporation of America first worked on directive antennas for short wave, long distance communication in 1923.

The first work done by the Radio Corporation of America, so far as I can recollect and am aware of it, was done at Belfast, Maine, and I was one of those engaged in the tests which were made there. In the very first directive antenna experiment, Mr. H. H. Beverage, Mr. S. W. Dean, who was at that time my assistant, and myself, transmitted from Belfast, Maine, to Riverhead, Long Island, where Mr. H. O. Peterson made observations of the received signals and following that, throughout the early part of 1924, I spent all my spare time in doing directive antenna experiments at Belfast, Maine.

That Belfast station was established primarily for the purpose of receiving long wave trans-oceanic signals from Europe and relaying them on down to Riverhead, Long Island, and from there into New York City; that was commercial communications.

We were using, for receiving those signals from Europe, what was known as the Beverage wave antenna, which consisted of the equivalent of a pair of wires about ten miles or one wave length long, and these wires gave an antenna with a considerable amount of directivity for reception of long wave signals. These wires were directed in the direction of the signal to be received. They were just two wires side by side on telegraph poles; the antenna looked very much like an ordinary telegraph line.

As to what we did there in 1923 and 1924 in the way of trying to send, or sending, short wave radio signals from [fol. 51] the antennas which we had there, our first experiment, that I mentioned before, was done by taking a section of that long wave receiving antenna and using it for transmission. Its direction happened to be pointing very close to Riverhead, a direction opposite to Europe. So one Sunday we applied energy to the end of that antenna from our transmitter and had Peterson at Riverhead observe the received signal as compared with the signal from our normal relay antenna. For the purpose of that test the line of the wave antenna was cut off at about 4600 meters, as I recollect, and there we placed a resistance between the antenna and ground, with the object of making radiation unidirectional, if we could. That is, we cut into this long antenna to get the length we wanted, and then we used that section. We thought that if we made the length too great for the wave length which we used for transmission, the directional effect probably would not be so good as if we used a moderate length, so we cut it off at a little less than three wave lengths. The wave length that we used for relaying to Riverhead was 1620 meters.

We used other antennas and other wave lengths in our experiments there. A week after this first experiment, we set up a very small model of wave antenna on the station grounds, it was about one meter high and ten meters long, and we used a wave length of twelve meters. The energy was applied to one end of the antenna and we carried a receiver around the antenna to try and find the directional characteristics and apparently there was an appreciable amount of directional effect in line with the antenna in the [fol. 52] direction away from the end at which the energy was applied. We tried out three different types of antennas there, altogether. We built another one, later on, whose length varied according to the experiments being made. I think the greatest length that I used was 1400 meters. I made many changes in that antenna in an attempt to find a means of producing a good short wave directional antenna. None of the antennas that we worked with there for transmitting short waves went into commercial use at that time as a result of these experiments. We did not develop any antenna at that time that was sufficiently promising to

continue with, as a line of development; none of them seemed good enough at that time.

In the latter part of 1924, RCA began to use short waves commercially.

In the latter part of the year, probably about September, a transmitter was installed at the Tuckerton, New Jersey, station, which operated on wave lengths in the neighborhood of 100 meters. I haven't the exact date of that.

They were using short waves for sending to California, Buenos Aires, and other places, in 1924. This first transmitter was installed primarily for operation to Europe and Buenos Aires, Argentine, and it was followed in the same year by two other transmitters at New Brunswick, New Jersey, and two at Rocky Point, Long Island, and one at Bolinas, California. The transmitter in California was for transmission to Hawaii and the Orient. These were all commercial circuits. No directional antenna was used in these transmitters at the transmitter end.

In the latter part of 1924 daylight signals were received for the first time from England. Short waves were used. [fol. 53] This reception was carried on at Riverhead, where our commercial receiving station was located, at Cape Cod, where we had a marine station, and I think at one other point, perhaps Tuckerton.

After our work at Belfast, RCA did not immediately continue experimental work on directive antennas, as far as I know. They discontinued it because in 1924 the General Electric Company took over the program of directive antenna development, and we were not permitted to duplicate their effort because of the expense, so we withdrew for the time being. At that time, the Westinghouse Company and General Electric Company were the engineering concerns in the development of this work, and RCA was a communication company only.

As to my familiarity with the work that was done by the General Electric Company in its development of short wave directive antenna, I had the job of attempting to keep familiar with the work carried on by General Electric and Westinghouse Companies for the benefit of RCA, and I made a number of trips to Schenectady and to East Pittsburgh, and on at least one occasion wrote a report on the status of their research and development along those lines. As to those in charge of this development for the General Elec-

tric Company, one group was headed by Mr. E. F. W Alexanderson, the man I mentioned before, and his ass tant was Mr. S. P. Nixdorf. Another group working independently, but not very far away, was headed by Chester Rice and E. W. Kellogg. A little bit later a third group engaged in directive antenna development, and this group was headed by W. R. G. Baker; under him two engineers, Levin [fol. 54] and Young, I particularly remember as being very active. As one familiar with this radio art, I think Mr. Alexanderson ought to be classed as almost a famous radio engineer, at any rate, he was a leading man in this country in radio communication development at that time, and Rice and Kellogg were also very well known at that time and very highly regarded, and Mr. Baker was the head of the radio department of the General Electric Company, so I think he was very well qualified too.

These General Electric engineers continued on development of short wave directive antennas for a number of years, from about 1924 until 1926, intensively, and to some extent they continued with their work afterward, but so far as I know, substantially no commercial use has ever been made of the antennas which they developed or attempted to develop. They did develop some directive short wave transmission antennas, and they have been used for various experimental purposes, and perhaps for some broadcasting work.

Mr. Alexanderson and Mr. Nixdorf spent a large proportion of their time on development of large loop antennas and a little bit later they worked with arrays of di-pole antennas, hung up from steel towers. Rice and Kellogg worked on a form of multiple tuned antenna, and it was somewhat similar to the antenna which had been developed by Alexanderson, and later, engineers under Baker did some work on similar types of antennas and also some smaller types, such as vertical wires.

The General Electric Company's very active program terminated in 1926. As to why they discontinued this work [fol. 55] in 1926, my understanding is at that time the engineers were also interested in other developments, and in that same year the Marconi Company developed or demonstrated the beam system between England and Canada, which was so successful that it looked as if that type of antenna would be adopted as standard, and General Elec-

tric's efforts slacked off. That is what is commonly referred to as the British beam antenna.

As to what the RCA did in the way of adopting or using this British beam antenna in 1927, one of these antennas was erected at Rocky Point for transmission to England and a similar antenna was erected at Riverhead, for reception.

Q. 52. Mr. Hansell, now will you please tell us in a general way what that British beam unit was, and in this connection I hand you, so that you may use them if you see fit in your answer, a blue print which is marked Marconi's Wireless Telegraph Co., Ltd., London, No. 32251/1 entitled "Schematic Diagram of Feeder Circuit & Aerial, Beam Stations" and also a blue print marked Marconi's Wireless Telegraph Co., Ltd., London, No. 35567, entitled "General Arrangement of Aerial & Reflector System Beam Transmitter, Rocky Point, New York." You may state what those prints are, if you know, and then briefly describe the antenna structures as shown by those prints.

A. Drawing No. 32251/1 is a schematic diagram to illustrate the Marconi beam antenna. This was furnished to RCA in 1926 at the time we were negotiating with the Marconi Company for the erection of one of these beam antennas. This drawing has been kept in the files of our head office at 66 Broad Street.

It shows in a general way the type of radiators used [fol. 56] and the feeder system for energizing those radiators.

Drawing No. 35567 is a construction drawing showing in outline the Marconi beam antenna which was erected at Rocky Point in 1927. This drawing has been kept in the Rocky Point station files for use in connection with maintenance of the antenna since it was erected.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit No. 14 the Marconi Wireless Telegraph drawing No. 32251/1 referred to by the witness.

(Marked Plaintiff's Exhibit 14 in evidence.)

Mr. Brown: And as Plaintiff's Exhibit No. 15 Marconi Wireless Telegraph Company drawing No. 35567 just referred to by the witness.

(Marked Plaintiff's Exhibit 15 in evidence.)

Q. 53. Will you please tell us in a general way what the structure of that antenna is and how it functions?

A. This drawing No. 35567 of the Marconi Company shows first of all three steel towers for supporting the antenna system. Those towers are each 300 feet high and have 75-foot cross arms at the top. Between the cross arms can be seen a system of cables. There are four cables in all for holding up two curtains or arrays of radiators. On one side of the center line of the row of towers are 32 radiator wires, each one of which is made up in a considerable number of sections, one above the other, and the sec- [fol. 57] tionalizing is indicated by means of what look from here like dots on the wire. Actually at those points there are very loosely wound coils, or a structure which serves the same purpose, for reversing the phase of currents in adjacent sections of each radiator. The result is that this whole system of radiators carries current which flows upward in all the radiators simultaneously or downward simultaneously. The coils that I refer to are shown on the other drawing that was mentioned a moment ago, that is, those criss-cross arrangements in the middle of the vertical line. Those in effect are the equivalents of extensions of the radiator wires, but, being folded up, they radiate very little, and consequently they gave the effect of a wire in which the radiations from alternate half wave sections are suppressed, and that results in the currents all flowing upward simultaneously in all the radiator wires and all parts of the radiator wires.

Behind the 32 radiator wires was placed a curtain of tuned reflector wires. Each of the reflector wires was made up of a series of half wave sections so adjusted as to be substantially tuned for the wave length being used on the antenna. The result was that waves leaving the 32 radiators left in both directions, forward at right angles to the line of towers and backwards at right angles to the line of towers, but the reflectors reversed the radiation in one direction and sent it back through the antenna and forward in such a phase that it added with the radiation in the forward direction so that in effect the radiation from both sides of that radiator system was made to go out in a single direction.

[fol. 58] It may be worth noticing the particular arrangement of the suspension cables between the tops of the towers.

It will be noticed that instead of running straight across, those cables are bent in a curved shape. When the first Marconi beam antennas were built, a single cable was used to support the antenna, and reflector, but serious trouble was encountered with that arrangement because of the wind bellying out the antenna in such a way that the radiations from the center portion would no longer add with the radiations from the end portion and the directivity was spoiled. So this double suspension system was resorted to, to reduce that swaying of the antenna in the wind.

Another important feature from the mechanical point of view is that each of these radiator wires forms a span against which the wind exerts a pressure at right angles. A relatively small amount of pressure at right angles to that span of wire can produce a relatively great tension at the point of support on the suspension cable.

That is a very well-known principle, that if a wire is stretched tight and a force applied at the center there is a resulting force at the ends very much greater than the force applied at the center. Similarly, this multiplied force applied to the suspension cable at these 32 points is applied to the suspension cable between the tops of the towers, and the actual force is very greatly multiplied for the same reason. The result is that the towers have to be made very heavy and very strong so that they will stand that great multiplication of force.

Those towers are marked 650 feet apart on the drawing, and that is my recollection,—650 feet between towers.

[fol. 59] That British beam antenna erected at Rocky Point is still in use. It has been in commercial use ever since it has been erected.

The receiving antenna at Riverhead is not still in use; its use has been discontinued for some time.

The experience of our company, in the matter of maintaining this British beam antenna in working condition, hasn't been any too good. Soon after the antenna was erected we began to have failures of these radiator wires due to breakages near their top suspensions. Those breakages became so frequent we had to replace the whole radiator system with heavier material; and we made that material as heavy as could be permitted without danger of pulling down the towers and supporting cables. But in spite of that the breakages still continue. Only yesterday I noticed five of these radiators were down on that antenna.

We have had a windstorm take out substantially all of these wires.

This is a photograph of the British beam antenna as erected at Rocky Point.

Mr. Brown: I will offer that in evidence as Plaintiff's Exhibit 16.

(Marked Plaintiff's Exhibit 16 in evidence.)

The Witness: I have at various times, in connection with our antenna development, tried to find out what the cost of that British beam transmitting antenna as it was erected at Rocky Point is, but the records were kept in such a way that I never was able to find out an exact figure. But we have found out the cost of various parts of the antenna [fol. 60] and estimated other parts for our own purposes, and the laboratory figure which we have used has been about $175,000. From the figures that we were able to find of the actual cost of that actual installation at Rocky Point, we were able to establish fairly definitely that the cost could not possibly have been less than $100,000.

The installation of this British beam antenna at Rocky Point did not end RCA's development and research on directive antennas for short waves. The result was that RCA again took up the development of directive antennas, and pushed it actively without waiting for results from the General Electric Company. RCA started its own efforts to develop a short wave directive antenna after 1924 at Rocky Point by means of the engineers in a group that was assigned to me; that is, under my charge. First Mr. Lindenblad was assigned to work under me on directive antennas, and shortly after that Mr. Carter and a number of others. Lindenblad had done a considerable amount of design work on long wave antennas; and Carter had taken part in the development of the Beverage wave antenna.

As a result of this development work at Rocky Point by these men, there have been four general types of directive short wave antennas developed and commercialized. We designated them as Models A, B, C, and D.

The Model A consisted of two horizontal feeder buses, across which were connected radiator wires and tuning coils. The dimensions of the radiator wires and tuning coils were so adjusted that the effective capacity of the feeder buses, considered as transmission lines, was tuned [fol. 61] out. That gave the feeder bus the equivalent of

almost infinite electrical velocity, and caused currents to flow in all the radiators in substantially the same phase. In making up the complete antenna a similar set of radiators with their feeder buses was erected parallel to the first and fed in 90-degree phase relation, with such a spacing as to get substantially unidirectional radiation. We began developing it in 1926 and the first full scale model was finished on April 3, 1927. The first commercial model, designed to handle commercial traffic was placed in service in September of 1927, and was operated on a wave length of 16.2 meters, for transmission from Rocky Point to Germany. This model A antenna was of the suspended or curtain type, somewhat like the English beam. It had a number of vertical wires with the feeder in the middle.

We described the Model A antenna fairly fully in a paper presented to the Institute of Radio Engineers by Messrs. Carter, Lindenblad, and myself. This paper was published in the October, 1931, Proceedings of the Institute of Radio Engineers. On page 1777 begins a section referring to the development of the Model A antenna. That continues to the end of page 1778. Some additional information is given on page 1784. On page 1790, in Fig. 10, is a photograph of one of the Rocky Point antennas, the Model A antennas, erected for commercial service from New York to San Francisco. On page 1777, Fig. 2, is an abbreviated schematic diagram of the type of arrangement used in the Model A. Equivalent circuits are shown again in Fig. 9, on page 1789, and a photograph of one of the antennas is shown [fol. 62] on page 1790. This photograph, marked 93900, which is on a larger scale, is a photograph of one of the commercially used type of Model A antennas; it is not the same one as shown in the paper, however, but is one that was erected at Rocky Point.

Mr. Brown: I offer that in evidence.

(Marked Plaintiff's Exhibit 17 in evidence.)

The Witness: The drawing marked Radio Corporation of America, Engineering Department, No. L-323, is an outline drawing of a model A antenna, or a portion of it at any rate, showing the dimensions in wave lengths. This drawing was made up in our laboratory and supplied to our design and drafting division in New York, so that they could make the designs of the commercial antennas, of which a large number were erected, based on this drawing.

Thirty-eight were erected altogether, referring to our records, in the United States, Philippines, Hawaii, China, Russia and Norway. So far as I know they are all still being used.

There were two means of making the tuning adjustment in this antenna. One was by means of coil adjustments,—the coils were installed between the feeder buses at a point of connection to the radiators,—and another method of adjustment was to vary the dimensions of the feeder bus. It was made in two parts and the spacing between could be varied. These coils do not show on the drawing before me; their position is only indicated by crosses. Drawing marked RCA V-622 shows the coils; in the center right-hand por-[fol. 63] tion of the drawing is shown the coil arrangement used for antennas where we never had sleet, where we did not have to worry about keeping sleet off the antenna, and in the upper left-hand part of the drawing is the arrangement of two coils, which we used when we had to make provision for sleet conditions.

The way that we adjusted these coils when this antenna was erected was to run a steel cable to the top of the poles at each end of a span and on that cable a man was pulled up in a boatswain's chair, and he had to be moved along this whole bus to make individual adjustments for each adjusting point in the antenna in order to tune it. These coils got out of adjustment once they had been adjusted. We had quite a lot of trouble with ice and snow bending them out of shape, and in some other cases, vibration due to wind would deform the coils and put the antenna out of tune.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 18 a drawing L-323, that has been referred to by the witness.

(Marked Plaintiff's Exhibit 18 in evidence.)

Mr. Brown: And as Plaintiff's Exhibit 19, the RCA drawing V-622 as referred to by the witness.

(Marked Plaintiff's Exhibit 19 in evidence.)

The Witness: The first one of these Model A antennas went into service at Rocky Point in September, 1927.

[fol. 64] The Model B was the next commercial model of the antenna developed at Rocky Point, but we worked on another type before it was commercialized. We called that other type an expanding wire antenna, which consisted of

a two-wire transmission line, starting with the wires close together at one end, and the wires progressively increasing in spacing as we proceeded to the other end; there was no cross-connection. Right at that time no commercial model of that expanding wire antenna resulted, but it did lead to the development of an antenna which we called a Model B. We actually used that diverging wire antenna and in several instances the experimental antennas were used to handle commercial traffic for some time. This diverging wire antenna was not as directive as Model A; I do not believe that the models that we had were any of them as directive as Model A.

The next development of directive antennas by our group was when we call a Model B antenna, which was made up by means of long straight wires, arranged in such a way that their radiations would add in one desired direction and not add or more or less oppose in other directions. The fundamental radiating unit of that antenna consisted of two long wires which were excited in phase opposition, and so placed that their radiations would add in two general directions and cancel in two other general directions. Then a second pair of wires was set up to change that bi-directional antenna into a unidirectional antenna. Model B was described and illustrated in the paper for the Institute of Radio Engineers that we referred to previously. The de- [fol. 65] scription of the development begins at page 1779 and continues to about the middle of page 1781. At page 1806, Fig. 23, is a photograph of a two-bay Model B antenna, and Fig. 24 shows more in detail the feeder arrangement for one of these antennas. A schematic diagram is shown on page 1805, Fig. 22-A.

The first full-sized model B antenna for test was finished by our company on February 7, 1929, and the first commercial model for traffic was placed in operation on April 4, 1930. It operated on a wave length of 16.55 meters, and transmitted from Rocky Point to Madrid, Spain. Up to the present time, 25 of these model B antennas have been erected by RCA.

The model C was very similar to the model B except that the four wires forming the antenna were arranged in a horizontal instead of a vertical plane. Another difference which we made was to feed these radiator wires at their centers instead of at the ends, but so far as directivity and radiation characteristics are concerned, they were quite

similar. This model C antenna is described in our I.R.E. paper just referred to. It is shown schematically on page 1805, Fig. 22-B, and photographs are shown on page 1807. A complete antenna is shown in Fig. 25, and a portion of the antenna including the feeder arrangement in Fig. 26.

The first full-scale experimental model C antenna was finished by our company on April 10, 1929, and the first model for commercial service was placed in operation on July 7, 1930. It operated on a wave length of 28.22 meters, and transmitted from Rocky Point to Buenos Aires, Argen- [fol. 66] tine. We have built altogether six of these model C antennas.

The model D antenna which was developed at Rocky Point was an antenna which in some respects had a similarity to the expanding wire antenna, in that it used the long radiator wires set up at an angle to one another, and excited at their adjacent ends in phase opposition. The angle between the wires of one of these antennas was made such that the radiations from the two wires would add in one desired direction along the bisector of the angle, but would add much less favorably or even cancel in other directions.

As far as I know, practically all of the directive antennas we have built to date, including the models B and C, are still in use.

This Model D antenna, to which I have just referred, is also described in our I. R. E. article. The description of the development of that antenna begins about the middle of page 1781, and continues to the end of page 1783. On page 1819, Figs. 36 and 37 are schematic diagrams of the V type radiator used in setting up the model D antennas. On page 1820, Fig. 38 is a complete schematic diagram of a two deck model D antenna. Fig. 39 indicates that two of these might be used to obtain additional directivity and Fig. 40 is a modified arrangement when sleet melting is required. There are also quite a number of figures starting with Fig. 41 on page 1822, and continuing, which show the directive characteristics of V type antennas, having various lengths of radiators, and corresponding angles for the V's.

This paper to which I have referred was delivered orally before a meeting of the Institute of Radio Engineers on [fol. 67] June 6, 1931, at Chicago, and was published in the proceedings of that Institute in October of 1931. I personally delivered the paper in Chicago.

In my opinion, I would say that this I.R.E. paper describing the models B, C and D contains sufficient information as to structure, arrangement, and adjustments to enable a radio engineer to construct and operate the antennas there described.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 20, the paper entitled "Development of Directive Transmitting Antennas by RCA Communications, Inc.", published in Vol. 19, No. 10 of the proceedings of the Institute of Radio Engineers, October, 1931.

(Marked Plaintiff's Exhibit 20 in evidence.)

The Witness: We set up the first full scale model D antenna for long distance tests in April, 1930, and made quite a long series of measurements with it, transmitting from Rocky Point to Marshall, California, and Koko Head, Hawaii, which are on substantially the same line. The first commercial model D antenna was placed in service at Bolinas, California, in November of 1930, call letters KWE, frequency, 15,430 kilocycles, that is approximately 20 meters wave length. There have been quite a large number of model D antennas erected, and including all the various modifications I have been able to locate in the last few weeks, there have been not less than forty of these erected [fol. 68] and operated by RCA and associated companies. There are a few which were more or less experimental ones which aren't in use, but I should say probably 35 to 38 of them are still in use.

My work as head of the RCA transmission laboratory at Rocky Point has made me familiar with the comparative costs of erection and maintenance of models A, B, C and D antennas, and of the British beam antenna. Naturally this is a portion of the development of any new type of antenna, to determine whether it would be economical to place it into use, and as a consequence of that, we spent quite a bit of time trying to determine relative costs. For our comparisons of the cost of erection of the models A, B, C and D antennas with each other and with the British beam antenna that was purchased by RCA Communications, we took a wave length of 20 meters as representative, since that is about the middle of the trans-oceanic band, which we use, and putting together all of the information we were able to collect at the time, we placed the cost of the Marconi beam

at $175,000, as I said before. To obtain the same power gain due to the directivity, in comparison with the half wave di-pole, the cost of the model A was $80,000, the model B $30,000, the model C $48,000—the model C, incidentally, is not recommended for that wave length—and the model D $5,000. These comparisons are based upon our estimate of these several antennas built at the same point and capable of delivering the same signal strength at a given point; they are based on the assumption of conditions similar to what we have at Rocky Point. At other locations, the cost of one type might be a little higher than another, or it is [fol. 69] possible that all of the costs might be higher or lower, depending on local conditions for obtaining material, and the character of the ground, and so forth.

As to the respective costs of maintenance in service of these several types of antennas, the Marconi beam has given us quite a large amount of trouble, and has required quite a large amount of maintenance. The model A was not quite so bad, but it also required considerable maintenance, but models B, C and D have required practically no maintenance at all.

As to how the models A, B, C and D and the British beam antenna compare in strength of signals delivered to a given point along the line of strongest directivity, that depends on the number of sections or bays of each antenna used; but assuming that one bay or section is to be used, then the comparative figures would be 10 for the model A, 16 for the model B, 17½ for the model C, 40 for the model D and 40 for the Marconi beam. I believe the figures are given in our I.R.E. paper for the A, B, C and D types, but not for the Marconi beam.

As to how the Marconi beam antenna and the model D compare with respect to the ability to deliver signal strength under similar conditions and similar distances, they are both capable of giving excellent directivity and a large amount of power gain, so that from the standpoint of directivity alone, there is not much choice between them. We can get the model D antenna to give us the same result we get from the British beam under similar conditions, and the cost of the model D is around $5,000 and the British beam between $100,000 and $175,000.

[fol. 70] RCA Communications has about 100, a little over 100, directive short wave antennas in service at the present time.

I spoke of a single bay of the model D antenna, as giving certain signal strength under certain conditions. I had in mind, as a single bay of the model D antenna, an antenna such as was shown in Fig. 38 on page 1820 of the I.R.E. paper. It consists of four model D type radiators, altogether, arranged as shown in the diagram.

If we left off, say, the two top V's of these single bays that I have talked about, I would estimate that the resultant change in effective signal strength under the conditions referred to, that is, the directivity, instead of being 40 per bay, might drop to 20 or 25 per bay. Then suppose we left off one of the two V's in a horizontal plane and used only a single V, that would give us a reduction in signal strength to one-half again or in the neighborhood of ten to twelve and a half.

RCA Communications has a number of single V antennas in service and has built others for temporary or experimental purposes.

We have measured the signal strength from the single V's and from the two single V's in the same horizontal plane.

I know in a general way what the English, French and German radio companies have used in the way of directive short wave antennas in those countries from, say, 1923 or 1924 up to 1930, particularly those companies associated with RCA in handling traffic. In 1924, I was asked to go to London with Mr. David Sarnoff, to attend a meeting where the development of short wave stations and equipment was to be discussed, and following the meeting I made [fol. 71] trips around England and to France and Germany to see what the engineers were doing on the development of directive antennas. Following that, I came back to the United States and made a report to my superior concerning it. In England, I found that they were working very intensively on the development of directive antennas and they, at that time, had worked out the general scheme and principles of the antenna which we now call the British beam, and they were at that time engaged in working out the detail mechanical features of it. The French, at Sainte Assize, under Mr. Chireix, were also very active in the development of directive antennas at that time, too, and had set up quite a large amount of experimental directive antenna installations at Sainte Assize station. The Germans

had not yet started development of directive antennas, but they were expecting to within a reasonably short time.

The only short wave directive antenna that I saw set up in full size for communication purposes in 1924, in any of these countries, was one which the Marconi Company had erected at Poldhu, in the southern tip of England, in Cornwall. This photograph is a general view of the arrangement of masts and the antenna system which I saw at Poldhu in 1924. The photograph has apparently been retouched considerably in order to make the wires and central parts of the system visible. I believe that a natural photograph would not show the antenna wires, but it does show the general arrangement which I saw there at that time. The antenna system consisted of a vertical radiator, a single vertical radiator wire, and around that had been [fol. 72] grouped a large number of reflector wires on a surface shaped according to a parabola. This antenna had been used by Marconi for experimental transmissions from England, in the general direction of Africa and in another instance towards the United States. To the best of my knowledge the Marconi parabolic antenna has never had any extensive commercial use for long distance communications; its ultimate or maximum obtainable directivity was too limited.

Mr. Brown: I will offer in evidence, if you please, the photograph referred to entitled "Poldhu Cornwall, 1923", as Plaintiff's Exhibit 21.

(Marked Plaintiff's Exhibit 21 in evidence.)

The Witness: The French developed an antenna having di-pole radiators formed by bent sections of wire up and down in sort of a grille work fashion, by means of which they obtained the equivalent of the currents flowing in phase throughout a curtain, just as was done in the Marconi beam. The mechanical features of the French antenna were double suspensions and heavy towers, and so on, substantially the same as the British.

I have seen the American Telephone & Telegraph Company short wave directive antenna at Lawrenceville, New Jersey. I saw it in 1929, probably in May, just before the station was opened for commercial service. Except for the details of the radiators, the radiators proper, the structure of the Telephone Company's directive antenna at

[fol. 76] Q. 142. Now, when you measure, you measure along a straight line, as I understand it, across the beam. How do you determine these particular points that are indicated in your graph?

A. We took our measurements in terms of relative power and made a correction for distance in accordance with the law that for the signal strength along the surface of the ground, the power falls off as the fourth power of the distance. We use this same law for correcting our own directive characteristics where we have to make such a correction.

Compared to our own practice, we used, for making these measurements, the same instrument that we had used at Rocky Point for making directive measurements of similar antennas.

Based on our measurements on similar antennas, the directive pattern from the single V type antennas, if they were properly adjusted, would not be very greatly different from that shown for WIU except that there would be a main beam of radiation in two directions along the bisector instead of in only one direction. Each of those beams for a given size of V would be a little bit broader, but of the same general character as shown here.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 24 the directive diagram and I will attach to it as Plaintiff's Exhibit 25 the tabulation of the figures.

(Marked Plaintiff's Exhibits 24 and 25 in evidence.)

The Witness: These V-shape figures on this map of the Sayville station are the V antennas of the defendant. We [fol. 77] had an opportunity to see and examine these antennas when we were there; Mr. Darby permitted us to walk all over the station property and we saw these double V, and these single V, and di-pole arrays shown there on the map.

Cross-examination.

By Mr. Darby:

The Witness: Referring to this last Exhibit 24, where we plotted antenna No. 1, the direction of the wave being sent out is just diametrically opposite to the direction in which the antenna wires extend—i. e., from the apex to the open end; the directivity is just opposite.

I haven't had any opportunity to examine the data that you supplied with reference to all of the antennas at the defendant's station. I have not given any study to what has been marked in evidence here as Exhibit 12. I have seen it, that is just about all. I haven't been asked to check it. I didn't check for examination any of the antennas at the time I visited the station to determine what stations a particular antenna served; I believe that at that time you advised us you would supply some additional information later. We did ask some questions, and I think you answered them very frankly, but I am unable to recollect at this time just how much we were told concerning where each antenna works. When this additional information was supplied to us, it was not referred to me for study. I am not sure that I recall being told that antenna No. 7, for example, supplied Buenos Aires, Camaguey, Seattle and New Orleans; [fol. 78] it is possible you did tell us that, but I can't be sure at this time. I have no recollection personally of checking that.

I have not been familiar with the use of antennae in wireless transmission and reception since about 1918, that is, commercial use, but only since 1924. 1924 is the first time I became familiar with the commercial use of a short wave antenna for transmission or reception. I have been familiar with the commercial use of antennae for transmission or reception since 1920. The first commercial antenna I had occasion to do anything on, was at Marion, Massachusetts, in the spring of 1920. It was at the transoceanic station of the RCA on Cape Cod for transmission to Europe. It had what we know as an Alexanderson multiple tuned antenna. The antenna proper consisted of a network of horizontal wires at a height above the ground, and at intervals connections were made to ground through tuning coils.

I also referred to the British Marconi beam system of antenna. Referring, for example, to Exhibit 14, and referring to the antenna that was erected at Rocky Point, this British drawing was not sent directly to me. I have seen that drawing in connection with our work involving the erection of that antenna.

I don't know of my own knowledge that this drawing did come directly from the British Marconi Company. It was not sent directly to me.

Lawrenceville as I saw it in 1929 looked very similar to [fol. 73] that used by the Marconi Company—that is, the British beam type. In my estimation, the cost of such an antenna as that used by the Telephone Company at Lawrenceville would be very much greater than one of our Model D antennas for the same service. I believe that would also be true in the matter of maintenance; I have no definite knowledge about it. They published descriptions of this Lawrenceville antenna of the American Telephone and Telegraph Company, as erected in 1929, as I saw it in 1929. The American Telephone & Telegraph Company has issued a pamphlet describing that system there. There is a copy of it here, reprinted from the Bell Laboratories Record. There is a picture of the antenna system on the front cover. There are other pictures inside. For example, on page 2 there is a picture apparently taken from an airplane, which shows the whole station with its double row of towers.

Mr. Brown: I offer in evidence as a plaintiff's exhibit the pamphlet of the Bell Telephone Laboratories, in so far as it describes the directive antenna at that station.

(Marked Plaintiff's Exhibit 22 in evidence.)

The Witness: I have made arrangements to determine the distribution of radiation from one of the defendant's double V antennas at Sayville. That was on April 19, 1934. I and two of my assistants, Mr. H. E. Goldstine and Mr. L. L. Young, measured the directive characteristics of the antenna No. 1, as we know it, WIU, 10170 kilocycles.

This drawing, marked DNY 91, is a map of the Sayville [fol. 74] station which we saw in the office of the engineer in charge when we visited the station at Mr. Darby's invitation on August 14, 1934.

Mr. Brown: I offer that map of the Sayville station in evidence as a plaintiff's exhibit.

(Marked Plaintiff's Exhibit 23 in evidence.)

The Witness: The antenna that we measured is in the upper left hand corner of this map, and the place where we measured was on Locust Avenue, which lies off the map to the westward, and in addition to Locust Avenue we made some measurements and observations around to the north side and back of the antenna to the east. I have made a

diagram or plot showing the results of our observations of the directivity of that antenna. This drawing that you hand me is a photostat of the diagram. The mapping of the diagram was done by my assistant, Mr. L. L. Young, and he and I together have drawn the directive pattern and added some of the other material to it. Our measurements indicate that this antenna had very good unidirectional characteristics of the type we would expect to get from one of our Model D antennas, of about the dimensions shown here, and as nearly as we could check, the direction of the main beam of radiation was in the direction of San Francisco, as indicated on the map.

I said that we measured around one end and part of one side. We didn't measure all the way around because the radiations off in the other directions were too low to measure with the measuring equipment which we had available. [fol. 75] This other paper that you hand me is a tabulation of measurements made on WIU at the time that I stated previously. The points of this tabulation used to plot the main diagram have been indicated by asterisks. Some of the points not associated with the main beam have been used but not marked on this tabulation. Also, we have not plotted every reading, off to the side of the main beam particularly, because the points would be very crowded and not much would be learned from it. You refer to some of the points plotted not being exactly in the border line or margin of this beam as to any irregularity that that indicates, we found from measuring our own antennas that the measurements are more or less sensitive to the shape of the ground and local conditions around the point of measurement, so these variations from what might be called the theoretical pattern are normal for that kind of measurement. The results that we obtained are as good as we would expect to obtain on any of our own antennas.

The Court: Is that to compensate for the variation?

The Witness: We could not compensate for that sort of variation because it is due to local objects, the ground or things which we were unable to evaluate, so it is our custom to draw in a smooth curve, trying to iron out those small irregularities.

These irregularities that appear on this graph do not indicate anything negativing directivity of these antennas. In spite of those irregularities, it looks very good.

But I have always accepted it as being a drawing which came directly from the Marconi Company. I have studied the drawing in a general way and think I understand what it intends to show. I have a knowledge of the so-called British beam antenna that was installed at Rocky Point, [fol. 79] and I think I am reasonably familiar with it. It was erected at Rocky Point and completed in 1927.

This station in Massachusetts was used commercially in regular commercial practice. It had previously been in commercial operation and it was placed in operation again about the time that I was there, perhaps shortly afterwards. It had been in commercial operation even previous to the spring of 1920. It was a station taken over from the Navy and they in turn took it over from the Marconi Company, as I understand it. So it had been in commercial operation for a good number of years, but not in the same condition as it was in 1920, though. The station had been rebuilt, and before it was placed in commercial operation in 1920.

When we erected this British beam system, we had an array of wires on one side of the line of antenna masts, and another array of wires on the other side of the masts to serve as reflectors. This gave unidirectional radiation.

In the first antennas of that type erected there was trouble due to windage which would vary the distance between the arrays of wire, but this construction was used at Rocky Point to reduce that source of trouble.

According to my recollection, I said that the array of wires that were used as reflectors were adjusted so that they were substantially tuned for the operating wave length, which would mean that they would pick up considerable current and cancel radiation from the primary radiator in one direction and give it back to add, in the other. For a certain spacing there would be an optimum phase relation between [fol. 80] the wires on one side and the wires on the other, but in order to attain this unidirectional characteristic with this sort of structure, there is no specific exact phase relation required. The spacing and phase relation are dependent one upon the other and could be varied. To obtain this addition, the spacing between the array of wires wasn't critical; for 100 per cent addition in the forward direction, there was a certain spacing that was optimum.

X Q. 234. In the first system that you built up in which you said you had difficulty because of windage changing the spacing between the two wires, what was the maximum?

A. I am afraid that you misunderstood what I said, the trouble was not due to the change of the spacing between the antenna and reflector, it was due to the center of the antenna being shifted back out of line with the ends. In the system as constructed at Rocky Point, we had no difficulty due to the changing in the spacings between the antenna and the reflector. In the first system that we erected, we never had any trouble from that source so far as the matter has been brought to my attention.

The wires were tuned with respect to each other by the adjustment of the length of the individual sections in the case of the reflector and by means of lengths and size of those folded up sections in the radiator portions. Tuning is an important and necessary feature in connection with antennæ. It is perhaps putting it a little too strong, to say that it is practically indispensable in antenna transmission, but as a general proposition it is best to tune an antenna in nearly all cases.

The space relation between the radiating antenna and the reflector, where you want unidirectional transmission, is [fol. 81] very important in some devices, but not so important in connection with the Marconi antenna, as it would be with some others. In the V type antenna it is important in order to obtain maximum radiation. In the case of the horizontal parallel wire type of antenna, there are always certain relations of spacing which should be followed for optimum directivity. Those adjustments may not be critical in most cases, but they are reasonably so.

On page 1778 of the article in the I. R. E. which I personally delivered, there is shown a type of antenna with gradually diverging wires, and I said that we built at least two or three of that kind. I can't remember specific dimensions of the wires, but we used various dimensions, ranging up to perhaps six or eight wave lengths, according to my recollection. It was hoped to use the effect of traveling waves on those antennas. I do not know whether, at the present time, we could call them traveling wave antennas, actually.

On page 1778 of Exhibit 20, the arrow shows the desired direction only in one direction. The desired portion of the action and radiation from that antenna was intended to be in the direction of the arrow. If we had succeeded with that model in obtaining a true traveling wave antenna, it would not have been necessary to tune it. In a true traveling wave

antenna, you do not need tuning, but that one as shown in the figure on that page was not a pure traveling wave antenna.

I can't see any relation between the use of an impedance matching device and the matter of whether or not the antenna is of a traveling wave type. If you have a traveling [fol. 82] wave, a pure traveling wave antenna, there is no possibility of reflected waves. And a true traveling wave antenna, if it is correctly designed, can be strikingly unidirectional in radiation.

X Q. 253. I show you two lobes, and ask you if they are characteristic of a traveling wave antenna type.

A. This general character of radiation—it is not indicated here which plane they are taken in—is more or less characteristic of some of the antennas built like Fig. 3 on page 1778, which were intended to be a pure traveling wave type.

Mr. Darby: May I have these marked for identification.

(Marked Defendant's Exhibit A for identification.)

The Witness: With reference to the British beam antenna structure that I became familiar with, we used a reflector in 1926 or 1927. That is not the first time that I personally was familiar with the use of a reflector with antennae. I am not sure when I first learned of reflectors, but my understanding is that Marconi had used them quite a long time before.

In the reflector that we used of the British beam type, I do not believe I would say that the reflector was virtually a duplication of the antenna but spaced from it, that is, from the radiator antenna; there was quite a large difference in the structure. It was excited only by radiation from the radiator portion. The term "parasitic excitation" has been used to describe that.

I cannot say for certain when I was first familiar with the [fol. 83] use of a spaced reflector of any type. I would judge that soon after I began doing active radio work in 1920, I must have learned of Marconi's spaced reflector of the parabolic shape. As to when I was first familiar with a reflector which was separately excited, that is, fed with energy from the transmitter, so far as I can recollect, now, Carter was the first one to suggest such a thing to me, and I think in 1921.

In order to obtain unidirectional characteristics, it is necessary to have a spacing between the antenna and the

reflector which is a multiple of a quarter wave length, and phase relation differing by 90 degrees. When I say I desire unidirectional radiation, I mean that the reflector is spaced in a direction or in the direction in which it is desired to radiate. I have known that, in connection with the fed reflector, since Mr. Carter told me in 1921, or thereabouts.

X Q. 269. In this same article of yours, Exhibit 20, on pages 1824 and 1825, you say, "Unidirectional characteristics is obtained by using a radiator system in the usual space and phase quadrature relation." When you say "the usual space and phase quadrature relation", you are referring to the principle we have just covered that you have known since 1921?

A. That is the space and phase relationship we had reference to, yes.

When we are using what is sometimes known as the parasitic reflector, it is not absolutely necessary that the same relation be obtained between the two antennae: for example, in the case of the Marconi beam, it is only necessary that the phase relation of the reflector be such as to cancel [fol. 84] radiation which would tend to pass through the reflector, so that still quite a good directional characteristic can be obtained without carrying out this exact relation that I speak about here. The best relation is not exactly the relation as expressed, the quadrature relation, but approximately.

When we speak of space quadrature relation, we mean that the spacing between corresponding points of the radiators is a quarter wave length or multiples of a quarter wave length, measured in the direction of desired radiation. When we speak of quadrature phase relation, we mean that the timing of the current in the corresponding elements of one radiator is a quarter-cycle or 90 degrees different from the timing of the currents in the other radiator.

X Q. 274. Now, in your direct examination, you described at length and amplified your description by referring to Exhibit 22, an antenna of the American Telephone & Telegraph Company. That, of course, is not the only antenna of the American Telephone & Telegraph Company that you are familiar with, is it?

A. It was the only one I was familiar with at that time in 1929, but I have heard of another antenna since that time.

I have more than heard of another antenna; I have seen models of it and had it described to me by telephone engineers. They call it the Bruce antenna. It is a short wave antenna. I can't remember now when I first saw or heard this antenna described to me. 1929 would be too early I think. It was probably some time after 1929, I couldn't place the date at this time without checking it up.

[fol. 85] X Q. 280. I rather gathered from your testimony that you desired to draw a picture of what prior to the commencement of this suit had been used commercially for short wave transmission, that was your purpose, wasn't it?

A. Well, I had no purpose; I only answered the questions that were asked of me. I haven't any purpose at all. I personally had no purpose in not referring to this so-called Bruce antenna. I know now of the existence of the Bruce antenna in commercial use. I do not know how soon after 1929 I knew of it. I may be able to find some idea of that, but I can't place the date accurately now.

As I understand this type of antenna, it is made up of the equivalent of two V's arranged in the shape of a diamond. And at the one end energy is applied to the antenna from a transmitter or transmission line, and at the other end a resistance or loss device is inserted that prevents reflections back along the antenna. It has also been used, as I understand, without that resistance at the end.

Referring to Exhibit 24, which is the directive pattern that I prepared at the defendant's station, the pattern that I have drawn was effected by measurements that we made outside of the property on which the antenna was erected. The line on the diagram "Limit of Plotted Measurement" continued out, does not show the limit of territory that we covered in making the measurements; we covered measurements around the whole—or perhaps, I should say, observations around an angle of about 240 degrees, as I recollect we attempted to take measurements out in this direction, that is to the right of the edge of the paper, but the radiation was extremely low, and there were indications [fol. 86] that what we did get was largely due to wires in the vicinity of the measurement, so that the only definite conclusion we could draw was that radiation in that direction was very small. We assumed that there were a number of side lobes which our readings or observations, made

at a considerable distance from the antenna, and outside of the property, indicated were present. So our readings and observations led us to the conclusion that there were side lobes; also we would naturally assume that, from our own experience with the theoretical and measured directive characteristics of similar antennas. Aside from measurements that we obtained from the side lobe which led us to that assumption, they were not of sufficient strength to lead us to believe they were used commercially to reach New Orleans; we did not form any conclusion about their having been used.

Our instrument by which we made those measurements was in an automobile and the antenna, which picked up the energy for us to measure, was at a height of perhaps 15 feet from the ground. And that is substantially true of all the measurements we made in the automobile. As to what I mean by "substantially true", so far as I can recollect, all of the measurements made to form the basis of that curve were made with the one height of 15 feet, but our antenna was adjustable to make it possible for us to drive under limbs of trees and things of that sort. It was more likely 15 feet than within a range of 10 to 15 feet, I think.

[fol. 87] Redirect examination.

By Mr. Brown:

The Witness: On this matter of the measurements, in connection with Plaintiff's Exhibit 24, our measurements—those that are plotted—were made along Locust Avenue. Whatever the considerable distance that was referred to by Mr. Darby was, the measurements were made along Locust Avenue across the beam. Our observations were clear around the bisector of the angle in both directions; as I said before, I think we covered an arc of about 240 degrees.

I was asked whether in a true traveling wave antenna, there is possibility of reflection on the antenna; there might be reflection on the transmission line to such an antenna.

The wave length used at the Marion, Mass., station was of the order of 12,000 meters, or about 40,000 feet. I believe that is something like seven or eight miles. The whole portion of the wires of that antenna starting from

the point where the wires were connected together at the building and including the leads going to the top, and the top itself, were all a portion of the radiating part of the antenna. The length of the upright or substantially vertical part that went up to the horizontal top of that antenna was perhaps on the order of 400 feet. I think the length of the horizontal portion was about three-quarters of a mile; I do not recall the dimensions in meters.

After RCA had purchased the British beam antenna for Rocky Point and Riverhead, they never bought any others; those were the only ones we ever bought.

That antenna at Marion was substantially not directive. [fol. 88] Mr. Darby: At my request, Mr. Blackmar has kindly given us a list of each of the claims of each of the patents in suit, which recites: "As at present advised, plaintiff will contend that claims of the patents in suit are infringed by defendant's antennas as follows:

"Lindenblad No. 2:

Claims 9, 10, 19 and 23	By all V antennas
"Carter No. 3.	
Claims 1-4, 28, 38 & 40	By all double V's
"Claims 10, 12	By Ant. No. 8
" 15,	By all V's
" 16,	By all double V's
" 34-36	By No. 2 (orig.), by 3 (rebuilt), and by No. 8."

JOHN V. L. HOGAN, called as a witness in behalf of the plaintiff, being first duly sworn, testified as follows:

Direct examination.

By Mr. Blackmar:

The Witness: My name is John V. L. Hogan; my residence is in Forest Hills, Long Island; and my occupation is that of consulting engineer.

My first interest in radio was as an amateur in 1905 or 1906, or thereabouts, perhaps earlier. In 1906 and 1907, I was laboratory assistant to Dr. Lee De Forest, in his development work of wireless telephony and the vacuum tube. In 1908 to 1910, I attended the Sheffield Scientific

School, taking an electrical engineer's course, and specializ-
[fol. 89] ing in physics and mathematics, but I did not complete the course since I left in the middle of the junior year, 1910, to join the National Electric Signaling Company at Brant Rock, Massachusetts. That was Professor Fessenden's radio organization. I remained with that company and its successor, the International Radio Telegraph Company, until 1921.

With the Fessenden organizations, I began as a telegraph engineer, and my work included the design and the investigation and the operation of many types of radio transmitters, radio receivers, antenna systems and accessory apparatus. With the organization, I became chief research engineer, and finally manager, and during that period of about ten years, I handled investigation, design and measurement problems in a large part of the radio field.

A considerable portion of my work had to do with the transmission of signals, the measurement of signal intensity, the effect of changes in antenna design on signal propagation, and in general studies of the radiating systems as well as of the apparatus connected with the radiating systems.

Since 1921, I have practiced as a consulting engineer, working for broadcasting stations, radio set manufacturers, the Federal Communications Commission, and its preceding body, the Federal Radio Commission, and others.

My work in connection with my consulting practice has included studies of apparatus, both transmitting and receiving, of antenna systems, both directive and broadcasting types, and of accessory apparatus.

[fol. 90] I am a fellow and past president of the Institute of Radio Engineers, and a member of its Board of Directors, a member of other technical societies, including the American Institute of Electrical Engineers, the Acoustical Society of America, the Society of American Military Engineers, and some others.

I have presented a number of technical papers, written a number of technical articles on radio matters. I have contributed to books on radio in conjunction with other authors, I have written one myself; I have made a number of inventions in the field, and, on the whole, my experience has been, over this period of about thirty years, more

directly in the practical field than in the theoretical field, although I have studied the theories involved in all of this work and used, as far as possible, the theories as a tool or a basis for the practical applications of the work.

The Fessenden Company during the early years was entirely an experimental organization. The experiments, however, were full scale experiments, if I may characterize them in that way, that is to say, at Brant Rock, for example, we had a transmitting station, with a 400 foot tower, which was entirely competent to transmit, and did transmit, signals over trans-Atlantic distances. All of the operations of the company, therefore, were on a commercial scale, though they were not used in those years, for the transmission of messages for pay.

In the later years, from about 1919, the company operated a ship to shore commercial radio service and had a number of coastal stations which were engaged in the transmission and reception of messages for pay.

[fol. 91] Q. 4. Will you please outline briefly a radio communication system, with the fundamental elements of such a system?

A. In general terms, a radio communication system is like any other communication system. All of them are fundamentally alike, because in every case the object is the transmission of signals representing an intelligible message, from one point to another point.

The transfer of those signals through whatever system is used represents the act of communication, of course. Every one of these systems, whether it be the wire telegraph or the ordinary telephone or the radio system, can be looked on as having three fundamental divisions, the first, a transmitter, the second, a medium extending outward from the transmitter, and the third, a receiver connected to the transmitter by that medium.

The functions of those three divisions of the system correspond, generally speaking, to the words "In", "Through", and "Out", the transmitter placing the intelligence into the system, the medium carrying it through, and the receiver taking it out for use by the receiving operator or the person at the distant end.

Although radio is like other communication systems in those general respects, it differs, of course, both as to the

medium that it uses and as to the form of the apparatus used in the transmitter and the receiver.

For example, in a simple wire line telegraph, the transmitting element may be only a telegraph key and the battery which supplies the power. The medium of communication is the wire, the telegraph line, and perhaps the ground [fol. 92] used for a return circuit, or perhaps a second wire. The third element, the indicator or the receiver is the telegraph sounder at the receiving end.

Now, in this ordinary wire telegraph, those three elements are tied together, so that the mechanical motions up and down of the telegraph key at the transmitter end are reproduced by the up and down motions of the sounder at the receiver end. The Morse code is used to represent the intelligence by combinations of dots and dashes, and thus the message is transferred.

In the case of a radio there is no tangible medium between the transmitter and the receiver, no medium other than ground, at least, and the waves with which we are concerned, are considered as traveling through the space above the ground. The medium generally accepted as carrying the radio waves is called the ether of space. There is some dispute as to whether or not there is such a thing as ether, but if there is not an ether, there is something else, which we might as well call ether, so I think that dispute need not bother us.

The radio transmitter is an apparatus that is designed to impress upon this ether of space a form of wave or electro-magnetic disturbance that will travel from the ending point through space to the radio receiver.

The radio receiver is another form of electrical apparatus. It is designed so it can abstract from space a certain amount of this signal energy, this wave energy, and can convert into a signal indication.

The controversy here is concerned with the radio transmitter. More specifically it relates to the arrangements, the [fol. 93] structures by means of which the electrical generating apparatus at the transmitter is enabled to impress upon the ether of space these energies or this energy which is represented by the electro-magnetic waves.

The specific portion of the transmitter with which we are concerned is, generally speaking, the antenna and the connections to it, rather than the details of the transmitting or receiving apparatus, and consequently, I think there is

no need to go into the details of either the transmitting or the receiving apparatus here.

Q. 5. Will you please describe the operation of a simple radio transmitter or transmitting system, with particular reference to what is involved in the present suit?

A. I have made a sketch marked "Elementary Diagram of Radio Transmitter," and it shows, by the usual symbols, the four principal parts of any radio transmitter. The first is marked 1, and is a generator of high frequency alternating currents.

The second part, marked 2, is a signalling device of some kind, and here I have shown it as a telegraph key, the simplest possible form of signalling device.

The third element, here marked "coupler", represents whatever means may be used for transmitting the high frequency current made by the generator over to the antenna or radiating system.

And the fourth part is the radiating antenna wire system, here marked "Antenna", but when taken as a system including not only the radiating wires, but the lead-in to the transmitter building and the ground connection.

With a transmitter of this sort operating, the generator [fol. 94] gives off a sustained stream of high frequency electrical impulses. When the telegraph key is pressed down, the circuit of the generator is completed, so that the energy from the generator may flow through the generator circuit and through the transformer or coupler, perhaps I should say, across the transformer or coupler, to the antenna system. So that the operation of the key turns on and off the high frequency current in the antenna wires. That is because when the key is up, the generator circuit is broken and no energy is applied to the coupler. By pressing the key for short and long intervals, the usual dot and dash signals are formed, those being represented by short and long streams of currents, high frequency currents, in the antenna system.

The antenna is adjusted or tuned by selecting its size, or by compensating for its constants by the size of the right-hand coil in the coupler 3, so that a substantial amount of high frequency current flows up and down in the antenna system, whenever the telegraph key is depressed, and the circuit from the generator to the antenna is thus completed.

The passage of this high frequency current in the antenna wires causes the radiation of radio or electromagnetic waves, and the greater the antenna current is, the more current there is in the antenna, the more power will be radiated in the form of waves from a given antenna system. As a matter of fact, the amount of power which is given off by an antenna increases as the square of the current in the antenna system, so that if the current is doubled, the power is quadrupled, and so on.

[fol. 95] I have spoken of the generator as producing high frequency impulses. It would be more nearly exact to say that the generator produces electro-motive result or voltage; that is, the force which tends to drive an electric current through an electric circuit, the current being the force of that electro-motive force applied to a circuit which is capable of carrying electric currents.

Perhaps I should also say that when that voltage is uniform and direct, always tending to produce a current in one direction through the circuit, the current which results is a unidirectional or direct current, a continuous current. But here we are concerned, almost entirely with cases where the direction of the voltage or electromotive force produced by the generator alternates. It is first in one direction and then in the other, and consequently gives rise to a reversing current through any of the circuits, so that the direction of current flow through the circuit reverses, as the voltage direction changes.

Q. 6. What would happen if the generator in this sketch were a direct current generator?

A. There would be no current flow through the circuit after the condenser marked C had been charged, because that is an alternating current circuit. If the condenser C were left out of the circuit, there would be a flow of direct current in one direction, through the coil at the left of the coupler marked 3, but after that current had attained its steady value, there would be no transfer of energy across from one transformer coil to the other, because the transformer can only transfer changing currents, such as are represented by alternating currents.

[fol. 96] Q. 7. And what happens if you apply direct current to an antenna?

A. You get only enough current to charge the capacity of the antenna, and then the condition is fixed; no more current flows until there is some change in the system.

Q. 8. Is there any radiation under these conditions?

A. No, except possibly a slight radiation during the time of charging; there is no radiation of useful wave lengths.

Q. 9. Will you continue with your answer?

A. With respect to these alternating currents with which we are concerned here, we should consider the fact that alternating currents generally include to and fro motions of current in circuits over an extremely wide range of frequencies.

For example, in power supply, lighting and traction systems, the current changes its direction in the circuits a matter of 15 or 25 or 60 times per second, and consequently the current is spoken of as a 15 cycle or a 25 cycle or a 60 cycle current, because a cycle is a complete change of direction, and the number of cycles per second, usually simply spoken of as the number of cycles, defines the frequency or the rate of change of direction of the alternating current.

That type of alternating current used in power practice is, so to speak, at one end of the range of currents considered in electrical engineering. At the other end we have very high frequency currents, such as are used in radio. Even those extend over a wide range of frequencies, and in radio we have radio frequencies of antenna current as low as ten or fifteen thousand cycles per second, and as high as many millions of cycles per second. It seems so strange to speak of a 15,000 cycle current as low, because that is [fol. 97] actually changing its direction of current flow 15,000 times in each second, but it is at the low end with respect to these radio frequency currents, because the highest frequencies change their direction millions of times in one second.

Intermediate to the power frequencies and radio frequencies, there are audio frequency currents, used largely in telephony and in radio where the frequency corresponds to the range of frequencies in a sound, audible sound, perhaps 15 or 20 cycles at the low end, to perhaps 10 or 12 or even 15 thousand cycles per second at the high end. Those currents we are not particularly concerned with here.

I spoke of a generator as producing an electromotive force or voltage. The value of that is measured in the practical electrical unit called the volt. The higher the voltage, the more the volts produced by any generator, the greater the electromotive force, or the greater the tendency to produce current in a circuit. The amount of current in an electrical circuit is measured in the practical unit of amperes, or if very small currents are involved in fractions of amperes; for example, one thousandth of an ampere is known as a milliampere. Here we are concerned with very large currents of the order of amperes.

What determines in the simple case the amount of current through a circuit is the voltage or force applied to the circuit and the property of the circuit called its resistance, the resistance being the property which tends to prevent the flow of current. That is measured in ohms, and the simple law is that the current through the circuit measured in amperes, equals the electromotive force applied to the cir- [fol. 98] cuit and measured in volts, divided by the resistance, so that the higher the resistance, obviously the less the current for a given voltage.

Q. 10. Is that resistance analogous to friction in a mechanical system?

A. That is correct.

Q. 11. And the voltage is analogous to pressure?

A. Yes, or force.

Q. 12. And the current is analogous to the amount of energy that may be flowing in some form, such as the amount of water flowing through the pipe?

A. Yes, it is not analogous to the amount of energy, but it is one of the components of energy, it might be analogous to the number of cubic inches of water per second passing a given point in a pipe, that would be analogous to an ampere.

Going back to this elementary diagram of a radio transmitter, I should point out that both of the circuits shown, namely, the circuit of the generator, and the circuit of the antenna, contain electrical units or elements having two other important circuit constants. With respect to the generator circuit, the parallel line symbol marked C represents the condenser which has the property of capacity or the ability to store an electric voltage or an electric charge. The coil indicated by the wavy line at the left of the coupler

3 has the electrical property of inductance, which is associated with the ability to set up a magnetic field due to the current passing through the coil or conductor.

Those same two properties of capacity and inductance are present also in the antenna to ground system at the right of this sketch, the inductance being contributed principally by the right-hand coil of the coupler, and the capac- [fol. 99] ity being contributed principally by the group of wires constituting the radio system, taken as one plate of the condenser and the ground below them taken as the other plate of the typical condenser which represents the property of capacity.

For any particular frequency in a circuit having capacity and inductance, the two may be balanced against each other so their effects cancel out, and broadly speaking, in that condition the circuit is said to be tuned. In general, when a circuit is tuned to a specific frequency, it will carry a maximum current for the amount of electromotive force that is applied to it, and consequently, it has been customary for years to tune radio frequency circuits in order to increase the flow of current in them.

Q. 13. Can you give a simple analogy in a mechanical system of the equivalents of inductance and capacity?

A. Yes, I think the simplest analog is that of a spring pendulum in which a weight is supported by a helical spring. The weight has mass which corresponds in the mechanical sense to inductance in the electrical sense; the spring has flexibility, which corresponds generally to the effect of capacity. Any system having the spring and mass elements when set into motion and left alone will have a tendency to vibrate at a particular frequency, and if it is driven by an external force, it will vibrate best when the external force has that natural frequency of the system.

The electrical case is quite closely analogous in that if an electrical circuit constituted principally of elements having capacity and inductance is shocked or excited, it will tend to vibrate at a certain frequency, which is called its natural [fol. 100] frequency; and if that circuit is driven by a periodic force from the outside, in general, it will vibrate most effectively, or in other words, develop the most current when the frequency of the driving source corresponds to the natural frequency of the circuit.

There are some minor effects produced by resistance which make the analogs strictly and in detail not applicable, but I think they give a graphic picture of the system.

Q. 14. And in the mechanical system, may the nature of the free period of vibration be altered by changing the weight or the mass of the weight or changing the elasticity of the spring or by both?

A. That is correct, and the same thing holds true in the electrical system; the resonance frequency, the frequency to which the system responds best, may be changed by varying the amount of inductance or the amount of capacity or both in the electrical circuit.

Q. 15. That completed your previous answer?

A. Unless there are other items that you would like to have me explain in further detail in connection with this sketch. I might point out that the patents involved in this suit have to do with the antenna system and the means for transferring electrical power from the generator to the radiating antenna system and not with the details of the generator or of the signaling system, that is, the key, and so on, shown in this diagram.

Mr. Blackmar; I offer the sketch in evidence entitled "Elementary Diagram of Radio Transmitter".

(Marked Plaintiff's Exhibit 27 in evidence.)

[fol. 101] Q. 16. Will you please give a simple outline of what radio waves are and how they are set up and propagated?

A. The simplest way to get an idea of what radio waves are is to consider them in comparison with other types of waves, which other types appeal directly to our senses. For example, we are not equipped, humanly speaking, with antennas that will respond to radio waves. Radio waves are passing through and by us all the time in these days of broadcasting, but we have no way to tell it in our bodies.

On the other hand, we do have receivers of sound waves in our ears, in the auditory system, tied in with the brain, and we have receivers of light waves in our eyes and the nervous system connected to them.

Sound waves are mechanical vibrations of any medium such as air. They will be produced by the vibrations of any moving body so long as those vibrations have frequen-

cies in the range of audio frequency, of which I spoke, extending from perhaps 16 vibrations or cycles per second up to 16,000 vibrations per second as the upper limit. So the prongs of a tuning, of a vibrating tuning fork, for example moving back and forth within that range of frequencies or at some frequency within that range, perhaps the frequency of c, 256 vibrations per second, those prongs are capable of giving off sound waves. What they do is actually to strike molecules of air in which they are immersed and those molecules of air collide with others, so that the successive collisions produce a wave extending out to greater and greater distances from the tuning fork and conveying sound energy from that tuning fork in all directions from it [fol. 102] as a source and at the speed or velocity which is characteristic of sound in air, namely, about 1100 feet per second.

When some of the vibrating air particles strike the ear drum they shake it or cause it to vibrate and produce the sensation of sound.

In the case of light the waves are not mechanical but are electromagnetic. They are conveyed through this medium which we are calling the ether of space. They have much higher frequencies than sound waves, and they travel at a much higher speed. The flame of a lighted match or a candle, for example, will cause space vibrations, electromagnetic vibrations in space that have a frequency of the order of perhaps five hundred million million cycles per second, that is to say, five hundred trillion cycles per second. Those vibrations react on the ether of space around the flame and they cause electromagnetic waves of that tremendous frequency. Those waves travel outward from the source of light at a very high speed, the speed being about 186,000 miles per second instead of the relatively slow 1100 feet per second characteristic of sound.

Q. 17. How fast in the metric system?

A. Three hundred million meters per second. The waves when they strike the eye of the observer stimulate its mechanism and produce the sensation of light. It is an interesting thing that the color sensation depends on the frequency of the vibrations. For instance, if the frequency is increased to about 700 million million cycles, violet light is produced as the sensation; if it is reduced to about 450 trillion, or million millions, of vibrations per second, the light sensation is toward the red end of the spectrum and

here we come to the analogy or the connection with radio [fol. 103] waves because if the frequency of these light waves, which are electromagnetic in character, is reduced below the lowest value that produces the sensation of red color, the waves still continue, the eye cannot see them, but they become thermal waves, or heat waves, infra red waves, which can be detected to a certain extent by, for instance, reaction upon the human skin, or upon mechanical or chemical detectors of infra red rays.

Now, the radio waves that we are considering here are of the same kind as these light waves and heat waves, but their frequencies are still lower, really very much lower. The range of electromagnetic waves used for radio, instead of being measured in millions of millions of vibrations per second run from several millions on down to 10 or 15 or several tens of thousands per second. However, they do travel at this same speed of 186,000 miles per second and they are sent out from the radio antenna in much the same way as light waves are sent out from a flame.

The radio waves are produced by the rapid surging to and fro in the antenna wires of the high frequency currents that those wires carry, and the radio waves in the spaces around the antenna have the same frequency as the frequency of the current in the antenna wire that sets the waves up.

Going to the other end of the system, when the radio waves in space strike an electrical conductor, such as a receiving antenna wire, they produce in that conductor high frequency electrical currents having the same frequency as had the original current and as had the waves. Those currents produced in the receiving wire, when they [fol. 104] are let down to the receiving apparatus, used to operate a radio receiver or detector.

Q. 18. What is the relation between wave length and frequency and what values of each are used in radio?

A. In radio waves, and really in all other waves, there are two factors that are important. One is the frequency of the wave, to which I have already referred, that is to say, the number of vibrations per second, and by that I mean the number of complete vibrations per second, a complete to-and-fro swing of the wave, in other words, the vibration represented by a complete cycle of operations in the wave; the second factor is the wave length, and that is represented by the distance measured between two correspond-

ing points in the wave as it is set up in the conveying medium. For example, in water waves, the wave length is measured by the distance between successive crests of the waves or by the identical distance between any other two points on the wave which are at the same part of their swing.

Now, a wave progresses a distance equal to its wave length in one cycle and since it makes a certain number of cycles per second, which number of cycles we call the frequency of the wave, it is quite clear that in one second it must go a distance corresponding to the wave length multiplied by the number of vibrations in one second. That distance is then the speed or the velocity of the wave, and it follows, since the wave length times the frequency equals the velocity, that if we want to determine the wave length and know the velocity and frequency, we may simply divide the velocity by the frequency in order to obtain the wave [fol. 105] length, or, if we know the wave length and the velocity, we may divide the wave length into velocity in order to find the frequency of any particular wave.

In radio it is customary to measure the wave lengths in meters, a meter being about three inches more than one yard, or 3.28 times the number of feet. The wave frequency in radio is often measured in cycles, but more customarily in kilocycles or thousands of cycles per second. Therefore the velocity for radio waves is usually given in the terms of meters which are used for measuring wave length, and as I have said, works out, instead of 186 thousand miles per second, as 300 million meters per second or 300 thousand kilometers per second, the three values being the same and being the same as the velocity of light.

The practical beginnings of radio were in the late 1890's or about 1900, and in its first decade, up to about 1910, the waves used had wave lengths generally speaking of the order of several hundreds of meters, for example, 300 meters, 600 meters, or even 1000 meters.

In the second decade, which we can take as 1910 to 1920, there was a tendency to use, in addition to these waves of hundreds of meters in length, waves considerably longer. For example, waves were used up to 10,000 or 15,000 meters in wave length, even as high as 20,000 meters. Remembering that a mile is about 1700 meters, these longer waves are seen to run up to about ten miles in wave length.

About 1920, and in the third decade, the waves used began extending in the shorter direction to 200, 150 meters. Such [fol. 106] short waves had been used, of course, in the very early days of radio and during the war also, but those uses were not over great distances. One important reason for that was that powerful and dependable short wave transmitting apparatus had not been developed at the time of the World War.

I have made a little chart giving the relation between wave lengths and frequencies for a number of these typical values, and in each case have indicated both the number of cycles and the number of kilocycles in the frequency, and also the wave lengths in meters. These two measurements of the same wave disturbance in radio are interchangeable because the velocity is fixed, and in each case it represents simply frequency equal to velocity divided by wave length or the other side up, as I have explained.

Q. 19. With the result that the longer the wave length the lower the frequency?

A. That is right.

Q. 20. And vice versa?

A. That is right, the higher the numerical value of frequency the lower the numerical value of wave length, or the other way up.

Q. 21. And the only difference between the second and third columns is that the second column is a thousand times greater than the third column in each case?

A. That is right, because a kilocycle represents 1,000 cycles.

Mr. Blackmar: I offer the chart in evidence.

(Marked Plaintiff's Exhibit 28 in evidence.)

Q. 22. Will you please describe simple forms of trans- [fol. 107] mitting antennas and refer to the general characteristics of radiation of radio waves from them?

A. Yes. In the little sketch of Exhibit 27, that is, the elementary diagram, the antenna that is symbolically indicated there is the classical Marconi antenna, that is to say, the vertical, connected to ground at its lower end. The radiation from such a vertical antenna spreads out in all directions over the ground surface and travels along the surface of the ground. Of course, there is radiation at upward angles from the ground, but I am concerned at the

moment with the principal radiation which is along the ground surface.

That Marconi antenna has been the typical antenna used in commercial radio stations and in broadcasting stations for years, sometimes in the form of a single wire and often in the form of a multiplicity of antenna or aerial wires.

When the antenna masts or towers to support the upper end of the vertical wire were not tall enough so that the vertical wire alone would be large enough for effective radiation with a certain wave length, it has been customary to increase the electrical length of the system without increasing its physical length by connecting what Lodge called a loading coil at the ground end of the antenna wire, or by adding additional horizontal wires at the top of the antenna, the vertical portion, so making what has for a long while been called a flat top antenna. The coil of which I spoke added principally inductance to the antenna circuit. The flat top wires added principally capacity to the system. The addition of either of those tended to tune the antenna to a lower frequency because the larger the capacity or the larger the inductance in a circuit, the lower its resonance [fol. 108] frequency, and consequently, to make it better adapted to longer waves than would be the simple vertical wire.

The horizontal capacity wires at the top of the antenna, while increasing the electrical capacity of the antenna circuit in general, did not contribute to the practical radiation or in any event did not contribute substantially to that, the radiation being regarded as principally from the vertical section of the antenna.

The usual antenna had a vertical section which was considerably shorter than a quarter of the wave length, because, as your Honor can see, if even as short a wave as 300 meters were being used, a quarter of that would be about 75 meters or more than 200 feet, and it is difficult and expensive to get aerial structures of such great height. For still shorter waves and particularly in some of the more recent broadcasting applications, a single vertical wire, one-quarter of a wave length long, has been used as the antenna and that is strictly the classical Marconi form without horizontal conductors added to it, for example.

Now, when wave lengths less than 100 or 150 meters came into wider use in the early twenties or thereabouts, another

type of antenna became important in the art. That is the so-called half wave di-pole, and the half wave di-pole is simply a pair of quarter wave length wires placed end to end in a straight line so that the overall length of the pair is one-half wave length, there being one-quarter wave length on either side of the central point, which is where the energy is fed into the system.

Such a pair of wires was usually supported at some distance above the ground and might be turned either verti- [fol. 109] cally or horizontally or at some other angle.

A half wave di-pole of that sort, of course, would have extreme dimensions if the wave were long, but if the wave were of the order of 50 meters, say, roughly, 150 feet, the total length of the di-pole would only be 75 or 80 feet, which is not too much to build into reasonable antenna structures.

A pair of quarter wave length wires placed end to end and constituting a di-pole in that way when fed with the energy from the transmitter at the central point has a very real practical advantage in that it is able to radiate a large proportion of the power which is delivered to it. Another way of saying that is that the radiation efficiency of the di-pole is higher. By that, one simply means that the percentage of the power, of the total applied power, which is converted into radio waves, is a large percentage. In any antenna, as I pointed out, the power is proportional to the square of the current flowing in that antenna measured at a point of maximum current. It is also proportional to a factor called the radiation resistance. That is a measurable quantity which represents the opposition that the current strikes in setting up radio waves. If the radiation resistance of a radiating system is a large proportion of the total resistance of that system, it follows that the remaining loss resistance making up the total is small. Consequently, the proportion of radiation to losses is in favor of radiation and the system is efficient.

Q. 23. Mr. Hogan, in connection with radiation resistance, I have been more or less brought up to consider that [fol. 110] resistance was something you did not want. Is that so with respect to radiation resistance in an antenna?

A. Resistance is something you do not want if it represents a conversion into something you do not want. For example, resistance converting electrical power into heat

is certainly something you do not want in the wires going to an electric light, but if at the end of those wires you have a filament of an incandescent lamp, or, better yet, if you have a toaster, the resistance represented by that filament or the heater elements in the toaster is an important and useful part of your system.

Now, that same thing is true with respect to radiational resistance in measuring the useful effect, because it is the thing that you work against in producing the effect that you want, namely, the thing you have to utilize, radiational resistance, in order to get effective radiation. That, perhaps, is a crude and popularized way of describing radiational resistance, but it is strictly correct to say that the amount of power radiated into space depends upon the square of the current in the antenna system, and is proportional to this factor which we call radiational resistance; consequently, the higher that value for a certain amount of current, the more power will go into space. Similarly, the higher that factor is in proportion to the total resistance of the antenna, which is made up both of radiation resistance and unwanted or loss resistance, the higher the efficiency is of the radiating system.

That is why the di-pole was particularly good. It had and has a radiating efficiency such that well over 90 and often as much as 99 per cent of the power applied to the wire was converted into radiated waves; whereas, with the older [fol. 111] forms of antenna, such as the simple vertical wire, which usually included a tuning coil at the base, as I have said, and horizontal extensions at the top, a radiating efficiency of ten per cent, fifteen per cent, was considered high. Consequently, the rest of the power, the other 90 per cent or 85 per cent was used up uselessly in heating the ground, the conductors, the coils, and whatnot, and did not produce useful waves.

I think those two types of antenna, that is to say, the simple vertical Marconi antenna, with the ground connection, whether modified by the flat top wires or not, and the simple half wave di-pole, whether horizontal or vertical, are representative of the simple forms of transmitting antenna. And I think I have pointed out the general characteristics of radiation as to the amount sent out by each.

Perhaps I should go further in saying that with the Marconi antenna, constituted simply of vertical wires, or with the half wave di-pole arranged vertically above the ground,

the principal radiation with which we are concerned, extends in all directions around the antenna, travels out over the ground surface, north, each, south and west. The di-pole antenna does not radiate endwise, so that if the wire is vertical, and one is immediately above it, as, for example, in an airplane passing over it, strictly, practically no signal would be received. There are always some stray radiations, so that no one ever gets an exact zero except theoretically, but there is a point where there is in effect no practical radiation directly in line with the wire. That means if the vertical di-pole is turned so that its wires are horizontal, the principal radiation will be perpendicular [fol. 112] to the wire and not off its ends in either direction.

Q. 24. I think it might be helpful to refer to Fig. 1 of the first Lindenblad patent, in connection with radiation from a di-pole?

A. Yes, Fig. 1 of Lindenblad patent No. 1,884,006, is an approximate representation of the distribution of the field around a di-pole wire, which is marked 2 in this figure; that is to say, the vertical line in the center represents the half wave length wire itself, and the two circular figures or lobes on either side of that wire represent the distribution of the field intensity around the wire in a plane containing the wire.

There is a similar "figure 8", in any plane rotated around the wire. This line shows the intensity of the radiation in any particular direction from the center of the antenna system by indicating how far a line would be drawn in any particular direction, if that line had a length proportional to the field intensity delivered in that particular direction. Thus we can say that a line extending directly to the right would go all the way to the point marked 4, and represent a maximum intensity of radiation in that direction. On the other hand, a line in the direction of 45 degrees upward would strike the circle before the line was as long, and consequently it will be reduced, there will be reduced intensity of radiation in that particular 45 degree direction.

Going on to the limit, if the line were extended vertically or in the direction of the wire itself, it would strike the circle at the beginning, so to speak, and would have no length, indicating theoretically no radiation in the direction of the wire.

[fol. 113] Q. 25. Will you please explain the difference between point-to-point communication and broadcasting, as applied to radio communications?

A. The field of radio communications is divided, roughly, into those two categories, point-to-point and broadcasting. Of course, there is some overlap, as there usually is when one attempts to divide a large field into two parts, but that is an overlap as between the service rendered by certain stations, rather than the concept of the two types of communication.

Point-to-point communication involves the definite location of the transmitter and of the receiver. For example, with the transmitter in New York, and the receiver in San Francisco.

In radio, such point-to-point communication takes advantage of the fact that there is a free medium, the ether of space of which we have spoken, that connects any two given points where radio stations may be located. But the object of point-to-point communication, technically speaking, is the delivery by a particular radio transmitter of the strongest possible signal at, or as received at, a certain particular point, the receiving point.

Now, radio broadcasting is generally taken as the distribution either of information or entertainment or any other type of communication to a large number of scattered listeners. Of course, broadcasting, properly speaking, may also include the transmission of messages to ships or to aircraft or police automobiles, because one does not know the exact location of any of those things at a particular time, and because one may wish to send the same message to a number of them in different locations at the same time.

[fol. 114] Now, broadcasting uses, in addition to the natural economy of the free medium, so to speak, the fact that that medium provides a radial distribution, that is to say, a distribution in all radial directions from any particular transmitting point; and thus permits the waves to cover a wide area, surrounding any particular transmitting point.

The two types of service are really in strong contrast. One can see that broadcast radio must deliver signals over a wide area, a substantial area in order to be effective, whereas in point-to-point communications, it is only necessary to deliver the radio signal to a specific receiving point in a definite location.

In broadcasting, the service is more effective as the signal is spread out over more and more area, and as the intensity of signal throughout the whole area is built up to large values.

In point-to-point communication, the more powerful the signal is at the specific receiving point at which one is interested, the better the service is.

Q. 26. What is horizontal directive radiation and what is its utility in radio communication?

A. We considered briefly an example of horizontally directive radiation in discussing the di-pole arranged with the wire horizontal, because in that instance, the radiation along the surface of the ground extends most effectively in the two directions perpendicular to the direction of the wires, and does not extend in the direction of the ends of the wires. If the di-pole is vertical, we can imagine its radiation as spreading out in an approximately circular distribution over the earth's surface.

The radio waves in the case of the vertical di-pole then correspond generally to the distribution of the rays of [fol. 115] light from a light-house traveling out in all horizontal directions. That, of course, is the best distribution for broadcasting, because the signals can be heard in any direction measuring horizontally from the transmitting station, and they get out there with equal force in all directions, and they do not weaken in force with any specific direction, but only as the distance from the transmitting station is increased.

Now, it is evident that if one is working from a given transmitting point to a given receiving point, and if the signal energy is sent out in all directions, the energy which goes in such directions as are not that of the line connecting the transmitter and receiver, is wasted, because it continues going in its initial direction, and produces no effect at the particular receiver where one is trying to have the messages interpreted.

So that if we prevent the radiation of signal power in directions that are away from the desired line of transmission in point-to-point communication systems, and particularly if we concentrate the energy that is saved by preventing it from going in unwanted directions, so that that saved energy is also projected toward the receiver, it is possible to get a much stronger signal at the receiver, than otherwise

could be delivered with the same amount of transmitter power. In other words, the concentration of radiation in the desired horizontal direction, the direction towards the desired receiving station, results in a greater amount of power in the received signal, and consequently in a more reliable communication service, a better radio service.

This concentration of radio waves in the desired direction is analogous, of course, to the concentration of light waves, [fol. 116] by means of a reflector behind the light source, and contrasts in the analog to the circular distribution from the lighthouse.

Radio reflectors for concentration of this kind have been used. I think Mr. Hansell referred to the parabolic reflector that Marconi used at Poldhu in his transmission from there.

It is that concentration of radiated power so that it does not spread out horizontally in all directions from the transmitter that constitutes horizontal directivity in a radio system.

Now, by means of that directive concentration it is feasable to multiply the strength of the signal that is received at a given receiving point without requiring any increased power consumption at the transmitting station. That is to say, practical systems involving horizontal directivity do not merely add a percentage which would perhaps be thought of as just a small percentage to the intensity of the signal at a distance, but they actually multiply its strength so that a signal is several times as intense when received at the distant point when the energy is concentrated horizontally. That feature is of really great practical value in improving the reliability of radio service for a radio transmitter of a given power consumption or size.

And, of course, another way of saying that is that by using horizontal directivity one may attain an equally reliable service with a great saving in power, that is to say, by the use of a fraction of the amount of power that would be necessary if the energy were allowed to be broadcast in all directions.

[fol. 117] Q. 27. Now, Mr. Hogan, you have referred to the directivity diagram of the simple di-pole. Can you refer to a similar diagram showing directive radiation from an antenna? I suggest that you refer to the third Carter patent, Plaintiff's Exhibit 5, figure 3.

A. Yes, Fig. 3 of Carter patent 1,974,387 is such a diagram, showing the relative distribution or the relative concentration of the radiated power from a directive antenna system. The location of the antenna in these plots, as they are usually made in radio, is taken to coincide with the center of the diagram. That is to say, in this case, the antenna would be considered to have its center at the intersection of the horizontal line marked XX, and of the vertical line marked 90 degrees.

Now, the curved line on the plot shows the relative amount of power that is radiated in different directions from this center, and the curved line shows that amount of relative power by the distance that the curved line itself is from the center when a line is drawn to it in the direction in which we are interested.

One might consider that if one had a radiating antenna at the center where the lines intersect, and then imagined himself as projecting a line outward along the ground surface from that center of that antenna, and adjusting the length of that line so that it represented a ray in the particular direction in which it was pointed at any time, the end of the line, or the end of that group of rays would trace the path of this diagram.

Now, if a receiving station is in the direction of the XX line, either to the left or to the right, it is clear that the ray drawn from the center of the diagram to the curved line will [fol. 118] be a maximum length, and that indicates the maximum transmission of power in the direction of the line XX, either to the left or to the right. If our observing receiver is moved perhaps five degrees off of that center line up to an angle represented as half way between the XX line and the line marked 10 degrees, the radial line toward the receiver will have only a very short length to travel before it intersects the diagram of the plot of relative intensities, and that shows that as the receiver is moved about five degrees from the XX line, that the signal from an antenna having that particular radiating pattern will be very much reduced. It does not mean there will be no signal, because there is some radiation in all directions, but it does mean that the signal will be reduced by an amount represented by the ratio of the lengths of the two lines in the two directions of which I have spoken.

If our observing receiver is moved farther from the XX line, say about 12 degrees off the center line, the ray toward it will increase somewhat in length. Perhaps it is about one-tenth of that which was receivable along the line XX. That would mean that at an equivalent distance a receiver located in the line XX would receive about ten times the signal of one located in a line 12 degrees from that XX line.

Now, if the angle is further increased to about 20 degrees, the signal grows weaker. Then at 35 degrees, according to this plot, a stronger signal will be received, about one-fourth of the strength that would be receivable along the line XX.

If one went all the way around the circle on a diagram of this kind, he could thus find what the effective relative [fol. 119] power of the received signal would be at a certain distance in any direction from the transmitter, and consequently he could judge from an inspection of the plot the relative concentration of the power in any particular direction.

A diagram like this of Fig. 3 is really representative of an ideal condition, a theoretical condition, but it would be very unlikely that one would encounter such a condition in practice. That is because in any particular installation there are bound to be variations introduced to some degree by differences in the effectiveness of the radiating path in different directions, sometimes even by objects surrounding the transmitting antenna. And by surrounding, I do not mean completely enclosing, but in the neighborhood of the transmitting antenna, power lines, guy wires, other antennas, masts, all of which affect the plotting of a transmitting directive antenna in the neighborhood of the antenna.

Those effects, in many cases, are completely wiped out by distance, when one gets far away, but in taking the ordinary directive plot of a transmitter antenna, you will find usually variations that will be departures from the ideal case of this Fig. 3.

Q. 28. What type of directivity is shown in Fig. 3?

A. That is known as the bi-directive type, because the principal radiation is in two directions from the center.

Q. 29. And is there an example there of unidirective radiation from an antenna?

A. Yes, Fig. 6 on the same page of the patent, shows a pattern in which the principal direction is single or unitary,

that is to say, the principal radiation is to the right of [fol. 120] Fig. 6, and there is substantially no radiation, or at least very little radiation in the opposite direction.

Q. 30. Where is the antenna located in the case of Fig. 6?

A. The center of the antenna, as in the other case, corresponds with the intersection of the crossed lines.

Q. 31. That is to say, the horizontal and vertical line, both broken in this case?

A. That is correct.

Q. 32. Will you please continue as to directivity?

A. This type of diagram permits one to judge or to measure in principle, at least, what may be called the directivity of an antenna system. That directivity, generally speaking, defines the amount of power which the antenna radiates in a specified direction, usually the direction in which it is desired to communicate, as compared to the amount of power that would be radiated in that same direction, if, instead of the directive antenna one substituted standard comparison antenna carrying the same amount of power.

Q. 33. What is a common standard comparison antenna?

A. For horizontal V antennas, of the sort we are considering here, a proper comparison standard is the horizontal di-pole; that is usually used for measurements of that kind.

I have spoken of directivity generally in terms of the gain that the antenna under consideration would give as compared to a standard antenna.

More exactly, directivity is the ratio of the power which a particular antenna radiates in the given or desired direction to the average amount of power that it radiates in all directions. But that technical definition reduces to the other more popular figure, when one also considers the di- [fol. 121] rective pattern of the comparison antenna, so that it is proper to look at directivity as a measure either of the gain in comparison with the standard antenna or of the concentration.

To get an idea of the order of power of multiplication that is practical, I might say that a 40 kilowatt transmitter with an efficient directive antenna system is practically the equivalent, so far as its production of a received signal at a given desired point is concerned, to a transmitter of several hundred kilowatts or even one thousand kilowatt

power, if the transmitter were used with a broadcasting antenna. That is to say, power multiplications which are from six to twenty times are not at all unusual, so that instead of having the need of using a transmitter of 200 kilowatts power, it is perfectly feasible with a directive antenna to produce the same signal with say one-tenth or even one-twentieth of that power, 10 or 15 or 20 kilowatts, and consequently the cost of generating the additional 180 kilowatts of power is saved.

By that, I do not mean one can not get a still stronger signal by using 200 kilowatts of power with a directive antenna, but the equivalent signal would be to that radiated by a 2000 kilowatt transmitter and transmitters of that size have not even been built for these high frequencies.

These directive antennas give very, very real increases in the reliability of radio service, because that reliability depends upon the intensity of the received signal and the uniformity with which it is received as compared to the disturbance. The strength of the signal also contributes to the speed of signalling, because it is possible to send [fol. 122] messages more rapidly, more words per minute, with a strong signal than with a weak signal.

Q. 34. With respect to receipt of strong signals or weak signals, I would like to understand what it is you mean with respect to noise level. Will you define that word,—what it means as to the reliability of reception?

A. We grow in the habit of speaking of strong signals and of weak signals. They are comparative terms, of course. Amplifiers are available, and have been for years, so that what comes in as a weak signal can be made into a strong signal by the amplifier alone. However, that transformation of a weak signal to a strong signal does not give the useful effect that would be attained if a strong signal were produced in the first place at the receiving station. The reason for that is because what really determines the effectiveness of a received signal is how far it stands out above the residual electrical noises or static or other disturbances, which are always present in radio receivers. If, for example, one has a noise, an electrical noise level of ten units present at any particular time, and the signal has only twenty units of strength, it will be then twice as loud as the noise and will give a certain differential between the two.

If those two things are applied to an amplifier, so they are multiplied by ten, the same ratio still holds, and while the signal becomes 200 units, the noise also becomes 100 units; consequently the difference between the two does not stand out. The ratio stands fixed. On the other hand, if we think of ten units of noise and twenty units of signal, as much again for a given transmitter power, and we had a [fol. 123] multiplication of that signal strength by increasing the transmitter power, the noise has not increased as the result of that change, and the signal goes on up to many times the noise level. Consequently that gives a clean margin of useful signal which is distinguished from the noise and increases the reliability of the service and the speed of the service.

Q. 35. Please refer to the first Carter patent, Plaintiff's Exhibit 1, No. 1,623,996, and describe the disclosure there, —particularly with respect to Figs. 1 and 2.

A. The first paragraph of the specification points out that the invention relates to an improvement for transferring radio frequency energy generated at a power house to the antenna or the radiating circuit, the energy radiating circuit. By the power house here is meant the radio station. The generator is the radio frequency generator in the radio station. The antenna wires are the elements that I described in connection with the simple elementary radio transmitter as the elevated wires carrying the radio frequency currents and converting a part of, and perhaps a large part of, the energy represented by those currents into the desired radio waves.

The Carter invention solves two separate problems that had existed in the practical radio art for a good many years prior to the application date of June 25, 1933.

The first of these problems is that which has to do particularly with the part of the patent concerned with Figs. 1 and 2. This is taken up by Carter in the discussion at page 1, lines 7 to 31, where he points out that in the past it has been the custom to erect the antenna of a transmitting system as close as possible to the point where the radio frequency [fol. 124] power is generated in order to have a minimum power loss between the generator and the antenna, in the interests of efficiency and economy.

The power loss referred to in that part of the specification is the radio frequency energy generated by the high

frequency alternator or generator in the power house and applied to the system connecting it to the antenna, but which fails to get to the antenna because the connecting system is not adequately or properly designed to deliver the power without such losses.

Of course, whatever is lost on the way to the antenna is gone with respect to any ability to produce waves and again, of course, what we are trying to do in these radio transmitters is to produce all the radio waves we can, of the right kind, with a certain amount of power to begin with.

The specification continues, at line 13, to point out that circumstances occasionally arise where local geographical conditions or considerations of economy render it desirable to make use of an antenna which is located at a distance from the power house and that in the past, under such conditions, it was not possible to work efficiently, particularly with short waves, since a given length of transmission line, with such waves, represents a greater electrical distance than with long waves.

Q. 37. Have we already had in this case, Mr. Hogan, an example of lines 7 to 13, the transmitting system located as close as possible to the power house?

A. Yes; that was typical of the station arrangement up to the time of the Carter invention, and a specific case of that sort was described by Mr. Hansell in connection with the Marion, Massachusetts, long wave trans-Atlantic trans-[fol. 125] mitter, where the long antenna wires, speaking in terms of feet, were led downward directly to the transmitter house. Those wires were not long in terms of wave length, being only a fraction of a wave length in length, but they were brought directly to the transmitter house. That same consideration of length is what Carter refers to in the twenty-second line of the specification which I have just read, where he points out that when short waves are used, an antenna located a certain number of feet away from the transmitting house is a greater electrical distance for those short waves than it would be if long waves were used, the reason, of course, being that a full wave of the electrical energy is set up in the connecting system, in a distance approximately equal to one wave length, and consequently if the wave is short, there will be more of those

complete wave lengths in a line that is 600 or 1000 feet long.

Q. 38. In your experience is Mr. Carter correct in stating what the custom had been in the past with respect to the location of the antenna close to the power house?

A. Yes, absolutely. I know of dozens of stations which I personally visited prior to this time, and I don't recall a single instance in which the antenna was not brought directly to the transmitter house. That was the customary procedure.

Continuing at line 24, Carter points out that his invention has for its object the provision—I should say for its first object, he says, "for objects,"—the provision of a transmission line which will supply radio frequency energy from a power house to an antenna located at a considerable distance away, thus making possible the utilization of existing [fol. 126] apparatus at a high efficiency where hitherto only a low efficiency was possible.

There he distinguishes from what I have referred to as in my experience the usual practice in erecting radio transmitting stations so as to have the radiating antenna immediately adjacent to or as close as possible to the transmitter proper so that loss of power in transfer from the generator to the antenna might be minimized. That was recognized as fundamental procedure in the design of transmitting stations, and radio engineers knew that the large radio frequency currents in the lead-in, or the wire connecting to the antenna, were largely wasted from the point of view of causing useful radiation. It was because of that that we all made a practice of shortening that connection as far as possible by placing the antenna itself at or very near to the transmitting station.

I have indicated a situation of that sort in Exhibit 27, which shows how the generator and the tuning coils were usually placed together within the transmitting house and the lower end of the antenna connected directly to the tuning coil within the transmitter building, the ground connection almost invariably being made below the tuning coil in the transmitter house.

With respect to the conditions under which it was desirable to have an antenna further removed from the transmitter house, we might consider cases where the provision

of a good ground connection was difficult or where the ground in the neighborhood of a suitable transmitter house site was of high resistance or otherwise unsuitable for the radiation of electric waves, or where a number of antennas had to be provided and the bringing of them all together [fol. 127] at the transmitting house would be either impossible or inefficient at times because of the interaction between the closely located antennas.

Q. 40. Do you find an example of that in Plaintiff's Exhibit 23?

A. Yes; that is the map of the Sayville station and is an excellent example of a central building containing a number of transmitters and a large number of, a correspondingly large number of antenna systems in general, one for each transmitter, which it would be impossible to get to the transmitter house.

It had been attempted to meet situations of that kind by using what amount to long circuits from the transmitter house to the radiating antenna and tuning those circuits so as to produce a substantial amount of current in the circuit in spite of its length, but, of course, the act of tuning the circuit in general caused increased current in that circuit and consequently an increased loss for a given amount of power.

It had also been suggested that by transmitting a relatively feeble amount of power to a distant antenna and amplifying that power by vacuum tube or other amplifying system at the antenna, it would be possible to move the antenna away from the transmitter house.

Neither of those plans was of practical value, the long tuned circuit because of a lack of efficiency, and the distant amplifier because of its complication, and so far as I know, neither went into practical use.

Now, Carter illustrates his solution of this problem in Figs. 1 and 2 of the patent, and he describes it beginning at line 60 of page 1 of the specification. Referring to Fig. 1 [fol. 128] there is shown at 14 a generator or a source of power which corresponds to the generator that I marked 1 in Exhibit 27. This is coupled through a transformer having coils 13 and 12 to a transmission line which is marked 10 in Fig. 1 of the patent and which extends as a two-wire line over the considerable distance between the

power house and the radiating antenna which is referred to at page 1, lines 27 and 28 of the specification.

This line conveys the power from the transmitting generator to the antenna, the antenna being coupled to the line through the second transformer, having coils 11 and 2, instead of having its end connected directly to the coils 12 of the first transformer.

Q. 41. What is the type of antenna indicated diagrammatically at Fig. 1?

A. The antenna shown there is of the multiple tuned type, generally like that described by Mr. Hansell in connection with the Marion station.

Beginning at line 75 of page 1, Carter points out that in order to economize in the generating and power transmitting apparatus it is highly desirable that the apparatus should work at unity power factor, that is to say, that the current and voltage in the transmission line should be in phase.

He explains, beginning at line 84, that when the transmission is at unity power factor the losses in the line are at a minimum, that, of course, being the point for which he was striving. This minimum loss in the transmission line, which is the condition which obtains with the line operating at what is called unity power factor, he points out is a condition which may be obtained if the transmission [fol. 129] line is made reflectionless or of electrically infinite length.

That statement occurs at lines 86 to 88 of page 1 of the specification.

We have several ways of stating the same desired condition. Unity power factor is a rather technical expression, as is the corresponding expression of the voltage and current in the line being in phase. They both mean the same thing. The power factor is a trignometric function of the angle between the voltage and the current when represented in terms of time, and if the two, that is to say, the voltage and current coincide in time so that they rise and fall together, we have a condition where there is no difference of angle between the two (representing time in terms of angles), and therefore the cosine of that angle is unity, and that gives the unity power factor.

It is an engineering method of explaining the technical situation here.

The condition to attain that in a transmission line is stated in equally technical but perhaps less complex terms when it is said that the line is to be reflectionless or of electrically infinite length. The meaning of reflectionless in connection with a transmission line is not hard to visualize, because one can imagine the traveling wave of electric power, proceeding down the long line from the generator to the transformer which connects to the radiating system, and one can imagine very easily that if the energy traveling down that line is efficiently transferred to the antenna, so that it all goes into the antenna system, and is all available in the antenna [fol. 130] system for producing radiating waves, then there is no obstacle at the end of the line such as would produce the reflection of energy.

It might aid in picturing that condition to consider a rather crude sort of analog, which is apt, at least in some particulars. I have never pretended to be able to find an analog that is complete, because they do not seem to exist, but with respect to this matter of reflection one can imagine a trough or a canal, let us say, with a dike or dam or wall at the end, the canal being filled with water. If waves travel down that surface and if the energy of the wave spills over the top of the dam and is available to turn the water wheel below, the uniform progress of the energy represented by those waves is not disturbed. On the other hand, if the dike or dam or whatever we choose is made so high, that the water will not pass over it, it is quite obvious that the waves striking that will be reflected back and interfere with the passage of further waves, coming down, so that a mixture of waves traveling in the two directions will obtain in the canal.

Now, carrying the analog further, it is clear that whatever energy is represented by the returning wave is not available to do work at the load end of the canal, so to speak.

That is certainly not a complete analog, but it has helped me in fixing a picture of what may go on in systems of this kind.

The other phrase used in the patent, and to which I have already referred, namely, a line of electrically infinite length, states the picture from a little different angle. It is intended only to express the view that if waves are traveling down a line and that line is infinite in extent, they won't [fol. 131] come back, they do not reach at the distant end

any reflecting point which will turn them back, because the distant end is at infinite distance.

That term is used in electrical engineering to express a condition of absence of reflection which is the way it is used here, but, of course, in connection with a system where power is to be transferred from the generator to a radiating antenna, the line from the generator to the antenna is not equivalent to an infinitely long line with respect to the transmission of power, because no power would ever get through a line, if it was actually infinitely long. It is only a way of expressing the absence of reflection, which has also been stated in those same words, namely, "made reflectionless".

Carter continues, at line 89, to point out that under these conditions where the line is reflectionless or of electrically infinite length, no waves can be reflected back from the ends to interfere with the natural flow of energy into and out of the transmission line.

That is a summary of the more complete explanation that I have just endeavored to give.

Now in a transmitting system of the sort shown in figure 1, this two-wire line extending from the power house where 12, 13 and 14 are located, over to the antenna where the transformer 11 and 2 is located, may be physically relatively long, that is, its ends, where the transformer coils 12 and 11 are connected, would be separated, what Carter terms a considerable distance, such, for example, as would be electrically substantial and equal to several wave lengths.

If we were considering a 50-meter wave length, for example, that corresponds to about 165 feet, the trans- [fol. 132] mission line, ordinarily would be several hundred feet in length.

Now, Carter recognized that the loss of the power in such a transmission line was proportional to the square of the current in the line, and to the resistance of the line. He states that, beginning at line 80 of the specification, where he points out that "the power loss, including radiation in any transmission line is I^2R, where I represents current and R the effective A.C. resistance, including the radiation resistance."

There he is talking, not about the antenna, but about a transmission line, and he is stating, in engineering terms, that in order to reduce the losses on the line, the factors which define loss should be kept at a minimum value. He

does not say that in those words, but that is the normal engineering meaning of the definition of what constitutes the losses.

Now, in examining that, we see that since the power is fixed by the square of the current times the resistance, the total resistance, we want to have a condition in which the current in the line is not unnecessarily large, obviously we want to keep that current down to the smallest value which can transmit the power that we require to pass through the line at the voltage which will appear in the line, and that occurs at this condition of the unity power factor, to which I have referred, because under a condition of unity power factor, the voltage and current are going along hand in hand at all times, they are doing their utmost with respect to each other, and since the product of voltage and current represents the co-operation between the two and is the thing that [fol. 133] defines power, we there have a condition of maximum power with a given voltage and current in the transmission line.

Now, looking at the other factor which defines the power, namely, the total resistance R, which, as Carter states is the effective alternating current resistance, including radiation resistance, we see two things: First, that the mere conductor resistance should be minimized. That, of course, has always been well known, that if the losses in transmitting electricity through wire are to be minimized, the resistance of the wire should be minimized, but there is a second feature, namely, that that R includes radiation resistance of the transmission line.

That brings in the concept which I have not discussed, namely, that even a two-wire line, of the sort shown in the Carter patent, does radiate a small amount of power. Now, of course, our desire in such a transmitting station is to have the power radiated by the antenna and not by the transmission line. Consequently, an indication that R includes radiation resistance of the line is a teaching that that should be kept small in order to reduce again the losses in the transmission line itself.

Q. 42. At one place in your answer, Mr. Hogan, you say that for a wave length of 50 meters, the transmission line would be at least several hundred feet in length. I assume you did not mean that the length of the line would be determined by the wave length.

A. No, I simply meant that in a practical case a line several hundred feet in length; while that, thought of in feet, is not a great distance, it does amount to several wave [fol. 134] lengths at a practical wave, such as 50 meters; under these circumstances, that would be a considerable distance, as Carter expresses it. In other words, we must think of the distance in wave lengths, rather than the distance in feet when we think of the electrical distance or when we attempt to say what a considerable distance between a power house and an antenna is with respect to the use of Carter's transmission line.

Q. 44. Before you take up the method by which Carter secures this reflectionless line, is this reflectionless line equally applicable to other types of antennas than the ones shown in Figs. 1 and 2, for example?

A. Yes. Figures 1 and 2 both show the multiple tuned antenna. Fig. 3, for example, shows the simple old vertical type of antenna, and any other type of antenna or radiating system might be used such as the horizontal or vertical di-pole, to which I have referred, or the V antennas which we are concerned with here. In fact, any type of radiating system.

Q. 45. Will you explain how Carter secures his reflectionless line?

A. Yes, I have pointed out that the desired result of minimum current in the line and consequently a minimum loss along the transmission line could be had by preventing reflection of the energy from the remote end of the line, that is, the load end of the line, the end away from the generator. That prevention of reflection avoids the development in the transmission line of currents that represent the reflected energy.

Beginning at line 92 of page 1 of the specification, Carter points out:

"This result may be obtained by closing the transmission [fol. 135] line 10 at 11 in such a manner that the effective impedance at the load end of the line is equal to the surge impedance of the transmission line."

In that connection, I should first point that "closed" in the electrical sense is diametrically opposite to closed in the single physical sense, such as closing a door and preventing

the passage of anything through that door. When Carter says a line is closed in a certain way, he means that the ends of the line are connected together as by the coil 11 or in some other way a termination is made which electrically closes the line, but does not prevent the flow of electricity to the antenna system.

Now, the requirements that the effective impedance at the load end of the line shall be equal to the surge impedance of the transmission line is equivalent to saying that the condition, the electrical conditions at the end of the line away from the generator shall be such that there is no electrical discontinuity of the sort that would set up reflection, that that is nothing at the far end of the line which will prevent the energy from being effectively transferred from the end of the line into the antenna system.

Carter explains in the next paragraph what is meant by the surge impedance of the line. It is represented by the symbol Z_o, and is stated to be approximately equal to the square root of the inductance divided by the capacity. That surge impedance is thus a characteristic of the line construction, it is independent of the frequency of the currents carried by the line, and it is also independent of the values [fol. 136] or the adjustments of any electrical apparatus which may be connected to either end of the line.

The other factor referred to at line 95 is the effective impedance at the load end of the line. Now, that is the effective terminal impedance of the antenna because the antenna is what provides the load, and Carter's teaching is that the effective terminal impedance of the antenna shall be made to equal the surge or characteristic impedance of the transmission line.

Your Honor will perhaps recall that the impedance of any electrical circuit is its effective angular or geometric resistance for alternating currents. That is to say, it is a carry-all term, which adds up geometrically, the current-opposing effects of simple resistance, as it is observed in direct current circuits, and of capacity and of inductance. Those three factors all come into a determination of the value of the terminal impedance of a circuit.

Further than that, the frequency of the alternating current, applied to the circuit, comes into the measure of the impedance because of the fact that while the resistance part of the impedance does not change appreciably or practically with the frequency, the reactive effects of both inductance

and capacity in the circuit do change with the frequency of the current.

For example, given a certain amount of inductance, and that is to say, a certain size of practical coil, the higher the frequency of the current going through there, the more strongly the magnetic field produced by that current reacts, and consequently we say the greater the inductive reactance [fol. 137] of that particular coil will be. The higher the frequency of current, the greater the inductive reactance.

That is one of the three elements of impedance. With respect to a condenser the opposite of this occurs, the higher the frequency of current applied to it, the more current goes through the condenser, consequently we say the lower the capacity reactance of that condenser is, the capacity reactance decreasing as the frequency goes up.

Now, the combination of those three things, really those four things, inductance, capacity, resistance, all make up impedance, and the frequency value which determines the effect on impedance of inductance and capacity—all of those go in to determine the effective reactance and the effective impedance of such a circuit as the antenna circuit that we are speaking of.

Q. 46. May I try to summarize that in brief form, and tell me whether I am approximately correct: With respect to direct current the current is impeded or prevented from flowing to an unlimited extent by the resistance in that circuit. With respect to alternating current the same resistance tends to decrease the amount of current flowing for any given voltage or pressure, but in addition there are two other elements which tend to impede the flow of current through the circuit and those are first the reactance set up by the condenser or some other capacity, and second the reactance set up by an inductive coil or some other inductance; and that the sum of those three, the capacity reactance, the inductive reactance, and the resistance, is the impedance of the circuit to the alternating current flow?

A. That is absolutely correct except that one cannot take [fol. 138] the simple arithmetic sum of the three values, but has to consider them geometrically; but the general statement is entirely correct.

Q. 47. Now will you take up the surge impedance, please, Mr. Hogan?

A. Yes. This surge or characteristic impedance, of a transmission line. I think it can be seen from what I have said, is an entirely different thing from the effective terminal impedance of a load or circuit. In practical radio frequency transmission lines of the sort we are concerned with here, the surge or characteristic impedance depends only upon the amount of inductance and the amount of capacity of the line itself. Those values, that is, the inductance and capacity values, are usually measured for a unit length of the line. For example, per foot or per meter of the line. They are determined in these lines by the size and spacing of the two wires that make up the line. In other words, the surge impedance is also called the characteristic impedance of the line, and it is a physical electrical characteristic of that line itself, regardless of the length, regardless of what is in the line, regardless of what is connected to the line, and dependent only upon the inductance and capacity per unit length, as given in the equation at line 105 of the Carter specification. Inductance and capacity per unit length are in turn determined by the size of the wire—in these practical lines—by the size of the wire and the distance between the two wires. To take a practical value, in the transmission lines with which we are here concerned, the construction is a pair of No. 6 copper wires spaced 12 inches apart. No. 6 wire is quite heavy, nearly [fol. 139] one-quarter of an inch in diameter, and such a pair of wires, with the 12-inch spacing, produces, as I have said, regardless of the length of the line, a transmission line which has a characteristic impedance or a surge impedance of approximately 600 ohms; that is the figure which will recur during the description of the defendant's apparatus.

Q. 48. You have said that the surge impedance is different from the effective terminal impedance of a load or circuit. Is it also different from the terminal impedance of the generator?

A. Yes. The terminal impedance of a circuit—any circuit—even if it is a circuit that is so greatly elongated as to constitute a transmision line, depends on these other factors such as frequency of the currents carried in the circuit, on the total or series resistance of the entire circuit, on the total effective inductance and capacity of the circuit, and including the resistance and inductance and capacity of the apparatus connected at the ends of such elongated circuit, or constituting a closed circuit.

In general we have terminal impedance for any kind of an electric circuit, depending upon these various factors. It can be measured between two points in any kind of a circuit. On the other hand, surge or characteristic impedance is only applicable to what is called a circuit having a distributed constants, or smooth constants, not a single lumped inductance or capacity, but to a circuit such as is represented by a transmission line. Broadly speaking, this condition, defined by Carter at lines 93 to 97, namely, the adjustment of the resistance at the remote end of an electric transmission line, so that it equals the surge or characteristic [fol. 140] impedance of the transmission line itself, is called matching the terminal resistance, the end resistance, the load resistance, to the surge impedance of the line.

Now with respect to Fig. 1 of the Carter patent, coils 11 and 2 constitute a transformer, and by just adjusting the number of turns in each coil and the coupling between them it is possible to control the voltage ratio or transformation ratio of that transformer, and in that way the effective resistance of the tuned antenna system, as it appears at the primary coils may be controlled so as to equal in value the characteristic impedance of the long transmission line 10.

Fig. 2 of the Carter patent is very similar, except that the two-coil transformer 11 and 2 is replaced by an auto transformer or one-coil transformer marked 22 in Fig. 2 of the patent. Carter, at page 2, beginning at the fourth line, points out that in Fig. 2 the transmission line is closed through a suitable amount of coil 22, such that the effective impedance of this part of coil 22, with its antenna load, is equal to the surge impedance of the line, that is to say, the apparent impedance of coil 22 with the effect of the antenna load or resistance upon it, is changed by changing the amount of the coil which is connected with the line 10 so that at the terminals of the transmission line, where it is connected to the coil, there appears a resistance equal to the surge impedance of the transmission line.

By those adjustments he attains the desired reflectionless or so-called electrically infinitely long line in which the high frequency alternating current is represented by traveling [fol. 141] waves that flow along the line from the transmitter to the load end remote from the transmitter.

Those traveling waves represent a flow of energy from the transmitting generator to the radiating antenna, and the purpose of Carter's match is to get the maximum energy

from the input of the transmission line into the antenna for use in the antenna to produce electromagnetic waves. And to attain that result he sets up this reflectionless condition of matched terminal impedance to surge impedance such that there is no reflection, and no energy is wasted or prevented from going into the load, that represents the condition of high efficiency in the transmission line itself.

Traveling waves to which I have referred are waves which carry energy in one direction. They can be represented in a simple analog by the sort of wave which travels along a rope when the far end of the rope is left loose, is not tied to anything. One puts a kink in the rope, and the wave travels down to the end, and the waves are not reflected back because there is nothing to reflect them at the far end of the rope. Similarly, if one has a long kite-string, and sets up a wave motion on the string, if the kite is far enough away so that the waves are not transmitted that far, then there is no reflection, and you have an example of traveling waves.

Electrically these traveling waves in a transmission line are characterized by the fact that at the instant when the voltage at one point of the line is a maximum the current in the line at that point is also a maximum. Similarly, when the current at a given point is—when the voltage at a given [fol. 142] point is a minimum, the current at that point is also a minimum.

Further, in a line carrying traveling waves, the average value of the voltage or of the current all the way along that line is uniform. Now, such a condition exists in this line used by Carter for the transfer, the efficient transfer of power from his generator to his antenna. In contrast, if there is reflection from the remote end of the line, that is equivalent to setting up a reversed or reflected wave traveling in the opposite direction, and the reflected energy combines with the energy flowing from the transmitter so as to produce standing waves in the transmission line. Those standing waves cause the amount of average current or voltage measured at various points along the line to be different. If energy is not transferred efficiently from the remote end of the line to the load, reflection will be produced in that way and line efficiency will be reduced. If all the energy reaching the end of the line is efficiently transferred to the antenna or to the load so that it can be used to do work there, which is what we mean by speaking of the antenna

as a load, then there is no reflection, the line efficiency is high and the energy that is transferred is delivered to the antenna for producing radiation. Of course, where there is reflected energy it goes back into the line and does not get into the antenna, and consequently it is lost in so far as its availability for producing radiation is concerned.

Now, I have pointed out that reflection of energy causes a combination with the energy going from the generator toward the antenna and thus standing waves are produced, that is to say, a condition where the voltage and current in [fol. 143] the line is larger than when there is no reflection, the excess current and voltage that is represented by these differences in value, that excess (that is caused by the presence of the undesired standing waves produced by the reflection in the line) is a measure of and represents the energy that is wastefully present in the transmission line, in other words, a measure of the lack of efficiency.

The standing waves in the line represented by the combination of the two waves, one, the main wave traveling toward the end of the antenna and two, the reflected wave, are called standing waves because they have stationary positions in space where current is either a maximum or a minimum, just as when a cord is tied to a post and waves are set up in that, the waves will be reflected back, and by timing correctly one can get a condition where waves appear to move in neither direction but simply where the line changes from side to side and there is no indication of a progress of a wave down the line.

Summarizing, it can be said that Carter's result of high line efficiency for the transfer of power effectively into an antenna so that it may be radiated from that antenna, can be attained by operating the line at unity power factor or by maintaining the current and the voltage along the transmission line in phase, that is to say, with the maxima of both voltage and current occurring at any one point at the same instant. I think I have explained that is equivalent to unit power factor.

The third way of stating it is that it is attained by making the transmission line equivalent to one of electrically infinite length in the sense that no reflection occurs and that, of course, brings in the fourth statement that it is attained by [fol. 144] making the line reflectionless, and finally, that con-

dition, defined in any one of those ways is had by closing the transmission line, terminating the transmission line, so that the effective load resistance is made equal to the surge impedance, the characteristic impedance, of the transmission line.

Carter's discovery that he could connect a high frequency generator by means of a long high frequency transmission line of high efficiency, because of its adjustment of that character, the connection being to a remote antenna, provided a practical solution for that problem of separating the antenna and the transmitter house.

I have pointed out, I think, at page 1, lines 19 to 20, that this had been particularly difficult with short waves, and of course this solution of Carter's has turned out to be a practical success and it has been in continuous and extensive use for a number of years.

Q. 49. The Carter patent at page 1, commencing line 31, states that "Another object of the invention is to provide a new and improved system giving directional transmission, utilizing separate antennæ fed from a single source through a plurality of transmission lines." Will you please explain how this object is attained, referring to Figs. 3, 4 and 5?

A. Recognizing that the transmission line is an electrical connection from the source to the radiating portion and that its primary function, or, rather, that the primary function of the entire transmitting system is to convert as much as possible of the generated power into radiated waves, and, consequently, recognizing that the power must be conveyed from the generator to the antenna, the desirability of getting as much of that power to the antenna as is possible, is clear. [fol. 145] That applies not only to the arrangement of Figs. 1 and 2, where only a single antenna is involved, but also to the use of several antennas whose effects are to be combined in order to produce directive radiation.

At the time of Carter's application for patent No. 1,623,996, it was known that two antennas spaced a quarter of a wave length apart and electrically excited with equalized high frequency currents that differed in their timing or their phasing by one-quarter of a cycle would be expected to radiate more in a desired direction than in the others, and little if at all in the direction opposite to the desired direction. Carter shows in Figs. 3 and 4 of the patent such pairs of antennas spaced a quarter of a wave length apart, the fraction lambda over 4 at the bottom of Fig. 3 and at the

upper part of Fig. 4 representing the quarter wave length distance between the antennas.

The Greek letter lambda is the symbol customarily used to represent wave length and of course that, divided by 4, represents one-quarter wave length.

Fig. 5 in the patent shows a directive characteristic of the radiation of such a pair of antennas when they are equally excited in the right relative phase or with the right relative timing, that is to say, when the maximum current in each of the two antennas occurs at times that are separated by one-quarter of a period or one-quarter of the time of one cycle.

However, in applying his invention to the multiple antenna systems of Figs. 3 and 4, Carter did not merely arrange to deliver power to those antennas efficiently, but he solved other important problems in connection with the [fol. 146] combination of antenna elements for the production of directive radiation.

The arrangements of Figs. 1 and 2 that I have already described are not in themselves sufficient to take care of these other problems that arise when one has two or several radiating units of a directive antenna system and when one has to supply power to them as in Figs. 3 and 4.

I have referred, for example, to the loss of power by random or undesired radiation from a transmission line; that is a mere power waste in connection with the systems of Figs. 1 and 2, but in connection with directive systems, such as those of Figs. 3 and 4, it is not merely a power loss but it has an adverse effect upon the directive pattern, upon the distribution of energy. Where one is endeavoring to concentrate power in one direction it is all the more important to avoid waste in unwanted radiating directions.

Thus it is more important in such directive systems, that substantially all of the power radiation should take place from the antennas themselves and as little as possible from the transmission line connection between the transmitter and the antennas. The two wire lines that Carter shows with their wires relatively close together and consequently having—as I pointed out—small radiation resistance in order to meet the condition of minimum loss that he set forth at page 1, beginning at line 80, give a connecting system which even though it may be long, has little, if any, interfering radiation, and which conveys the bulk of the energy effectively from the generator to the antenna so that it may

be radiated from the directive antenna combination itself. [fol. 147] Because a reflectionless line conveys a certain amount of power with the lowest value of line current and voltage for the delivery or conveyance of that power, such small radiation as would exist in the case of the two wire line is therefore minimized by the matching that Carter teaches, because that matching reduces the value of current and voltage for a given amount of power.

Now, although the arrangement of Figs. 1 and 2 is adequate for conveying power efficiently to any kind of antenna system, it does not show how to maintain the correct phase displacement between the two antenna systems, which are driven from a source.

In directive systems like those of Figs. 3 and 4, it is important to fix a relative phase or time difference of the current in each of the two antennas and also to fix the relative amplitudes of those currents and it is also important to fix those in a stable way which will not be subject to erratic variations.

To do both those things, both being of importance, Carter matches both of his antennas to the surge impedance of the power line. Of course, the line from one antenna section to the other antenna section, may be only one-quarter of a wave length long, and therefore physically short and even electrically short, a fraction of a wave length, and because of that, the mere gain in efficiency that is produced in that section of the line may be of relatively small importance and one might think that the primary reason for using the match secured in connection with Figs. 1 and 2 would not apply to a directive system where the antennas are spaced by such a relatively short distance. However, because in a [fol. 148] matched line, such as is shown in Figs. 3 and 4, the voltage and current at any point of the line rise and fall together, and because the maximum of current and voltage at different points along the transmission, separated by any particular distance, any particular fractional wave length, always occurs with a phase difference that is proportional to that distance, when the line is carrying traveling waves only, there is provided in this matched line a simple and effective and stable way of determining the relative phase and amplitude of the currents in the two separate antennas.

When Carter further, in Figs. 3 and 4, drives the two similar antennas through matched transmission lines at points that are separated by a quarter of a wave length along this matched transmission line system, he arranges matters so that automatically the two antennas have generated in them enough currents that are of equal amplitude and which differ in phase by that same amount, a quarter of a wave length, which corresponds to 90 degrees or a quarter of a period, and that represents the desired condition for multiple antennas, such as are shown in Figs. 3 and 4.

With the Carter arrangement that desired difference in phase is fixed very simply and definitely by the mere difference in length of the matched transmission lines that supply the power to the two antennas and the desired equality of the current in each of the two antennas is also fixed by the matching.

Because of those two facts the condition that is needed is easily attained and also it remains stable and is independent of critical adjustments.

[fol. 149] Carter describes this as to Fig. 3, beginning at page 2, line 10, pointing out that the antennas are located one-quarter of a wave length apart, they are energized through transmission lines 10 and 10′, and that the same adjustment of the coupling coils 38 and 38′ is made as before.

By that he means the adjustment which matches the load impedance or resistance to the surge impedance of the line, so that those lines are matched or become of electrically infinite length with respect to their absence of reflection.

Similarly as to Fig. 4, which he describes beginning at page 2, line 22, he points out that the arrangement is substantially equivalent to that of Fig. 3, he describes the coupling between the transmission line and the antenna, and its adjustment to give an effective impedance equal to the surge impedance of the line. He also refers to the directional characteristic of Fig. 5, at lines 38 and 39.

With respect to the control of the phase in the antenna systems, which I have described, he says, beginning at line 40, page 2:

"It is to be noted that my transmission line lends itself particularly to directional systems comprising a plurality—

of antennae, since the proper phase relation of currents in the various antennae can readily be obtained with a maximum efficiency of transmission line."

Q. 50. In connection with Fig. 4, might occasion arise when both antennas 41 and 41′ are to be located at a considerable distance from the power house?

A. Yes, indeed; the distance between the antennas is [fol. 150] only a quarter of a wave length, and it would often be desirable, and perhaps most of the time as in the case of a single antenna, to locate both of them at a distance from the power house.

Q. 51. And in this case, applying the teachings of Carter with respect to his first object, would there be any matching of the load resistance to the surge impedance at point 13 or in the neighborhood of that point?

A. Yes, what one would do would be to match the surge impedance of the long line coming from the transformer house, and connected to transformer coil 13 in either Fig. 3 or Fig. 4, by adjusting the transformer of which 13 is the primary, so that the effective load at the terminals of the transmission line where it is connected to 13, would equal the surge impedance of the transmission line. In that way, the teachings of the patent with respect to the long line and separation of the transmitter and antennas would give the highest efficient transmission line.

Q. 52. Now, would you summarize the advantages as you see them of the disclosures of this first Carter patent, I mean the practical advantages?

A. Yes, I think they could be tabulated by saying first, the antenna, or antenna sections may be located at a considerable distance from the generator as Carter pointed out in the first part of the specification.

Second, in spite of that distance of separation, power could be transferred to the antenna system with a minimum waste.

Third, a number of antennae units could be combined to cause directive radiation without harmful effects of spurious [fol. 151] or undesired radiations from the connections through which the power was transferred to the antenna.

Fourth, by using a single generator to supply both or all of the antenna sections, there would be provided a fixed

phase reference, so that the relative phases of each of the antenna sections would be maintained with respect to a single source.

Fifth, the relative phases of the currents in each of the antenna sections could be determined merely by selecting the desired length of traveling wave or reflectionless transmission line.

Sixth, those relative phases could be maintained without the need of frequent adjustment or critical adjustment at any time.

And seventh, the currents in the several antenna structures could be equalized, or could be controlled and maintained in the relative values desired.

Those, I think, are the principal practical advantages.

There is another feature which flows from the use of these lines, which is of considerable practical importance, and that is that when it is intended to use a system of this kind involving a matched transmission line, a reflectionless transmission line, the transmitting unit, the radio frequency generator unit (and, of course, today they are usually of the vacuum tube type), can be designed so that it is intended for connection to a load of a standard value, as, for example, the 600 ohms, of which I spoke. That means that one can build such transmitters, designing them for a particular value of that sort, and then can use them any-[fol. 152] where with any kind of an antenna system, no matter how complex the arrangement of the antenna is, nor at what frequency it is operated. And by using the 600 ohm line to connect the transmitter to the antenna, the transmitter is worked under the conditions for which it is designed.

If one didn't have such a set-up, it would be necessary to consider the antenna design in designing the transmitter itself.

Q. 53. Now, will you please turn to the second Carter patent in suit, Plaintiff's Exhibit 2, Patent No. 1,909,610, and explain the general nature of its disclosure?

A. The application for this patent No. 1,909,610 was filed March 12, 1930, nearly seven years after the application for the earlier Carter patent, which I have just considered.

The second Carter patent describes a specific and an improved way of adjusting high frequency transmission lines so as to get the desired high frequency explained in the earlier specification; that is to say, this shows a specific way of providing the reflectionless match between the resistance of the load or antenna and the surge or characteristic impedance of the transmission line. That reflectionless match resulting in a transmission line of electrically infinite length in the way I have described.

Where the load is provided by an antenna system, in the case of this second Carter patent, just as in the case of the first Carter patent, the antenna itself may be of any type, such as the vertical wires that I have described, and that were illustrated in the other patent, or the multiple tuned [fol. 153] antenna, or the horizontal wires or di-poles or the V forms of antenna.

Beginning at line 4 of page 1, Carter says, that

"In order that the line transmit energy at best efficiency; that is to say, without reflection, it is desirable that the line be terminated by a load which equals in impedance the surge impedance of the line."

Q. 54. And as I understand it, that was the teaching of the first Carter patent, is that correct?

A. That is correct. This is a little more general statement, but the substance is the same.

He explains as his object in greater detail, beginning at line 14, and says:

"it is an object of my invention to provide a method and means for terminating a line to which a load is connected so that the termination means combined with the load presents the correct impedance to the line."

That again is, while more specific, a rather general statement, since it refers to the correct impedance which we have already discussed.

Then beginning at line 19, he says, more specifically:

"I accomplish this by connecting a variable reactance across the line at a distance away from the load such that the circuit formed thereby including the variable reactance, the line portion between it and the load, and the load, presents an impedance equivalent to the surge impedance of the line."

[fol. 154] That describes in more specific terms his new circuit for attaining the reflectionless or high efficient condition.

The variable reactance which is referred to at lines 23-24 is a capacity or an inductance. He connects that at a point or across a pair of points along the transmission line between the source of power at one end and the load which is at or near the other end of the line.

He selects the distance between the load and this point where the reactance is connected, so that the combined effect of that shunt reactance (that is to say, that inductance or condenser), of the resistance of the load and of the section of the transmission line between them, provides at the point where the reactance is connected, a value of impedance or of resistance that equals the surge impedance of the line.

Now, the specification describes several variations of this new matching circuit. Fig. 2 shows the source which is a generator marked 2, connected through the transmission line marked 6, to the load represented by resistance 4, at the right of Fig. 2.

The figure is explained briefly at page 1, beginning at line 81—and in greater detail on page 2, beginning at line 18.

Carter points out that in this arrangement of Fig. 2, the load resistance 4 is less than the surge impedance, and the distance between the point at which the variable reactance 10 is connected and the point of the load (namely, the end of the line) is to be not more than one-quarter of a wave length along the line.

He explains, at page 2, line 40 and following, that the same result may be had by connecting this reactance in the [fol. 155] third, fifth, and so on quarter wave sections. As when the connection between the load and the reactance is beyond the first quarter wave length point, or in the first quarter wave section.

Fig. 3 is described briefly at page 1, line 86 as being an arrangement for properly terminating a line wherein the load resistance is greater than the surge impedance of the line.

That is an opposite condition with respect to the relation of load resistance and surge impedance from that shown in Fig. 2. To provide the desired match under the second condition, the inductive reactance marked 12 in Fig. 3, is connected across the transmission line 6 at a point that is less than one-quarter of a wave length from the terminals

of the resistance load 4. Similarly, beginning at page 2, line 60, Carter explains that the connection may be made in a later or more remote quarter wave section of the line rather than the first, that is to say, in the third or fifth and so forth.

Beginning at line 28, at page 1, the specification gives the necessary information as to the use of either a capacitative reactance—that is to say, a condenser,—or an inductive reactance—that is to say a coil—depending upon whether the load resistance is greater or smaller than the surge impedance of the line, and also depending on how far from the load one may desire to connect the reactance across the line.

On page 2 of the specification, beginning at line 69, Carter refers to Fig. 4, and says:

"I have shown the actual values of the elements involved where a line having a surge impedance of 600 ohms [fol. 156] supplies a load of 300 ohms."

Then he goes on to point out, as is shown in that figure, that in that event, the capacity reactance of 840 ohms should be connected across the line at a point which is slightly less than one-tenth of a wave length from the load to the point or connection where the line is matched.

At the end of the specification, page 2, line 90 and following, Carter gives a tabulation which shows four different cases, the relations between the ratio of load resistance and surge impedance, the line section length, and the character of reactance to Z connected across the line.

In this tabulation in the right-hand column of page 2, the line section lengths are stated as less than one-quarter wave length and as greater than one quarter but less than one-half wave length.

Those two phrases define respectively connection in the first or the second quarter wave length sections of the transmission line as one measures distance from the resistive load toward the source.

Beginning at line 41, and again, at 63, on page 2, Carter points out that connection in either of these first two sections, that is, the first quarter wave section or the second quarter wave section is preferable.

He also shows, though, at page 1, beginning at line 60, that similar results can be obtained when multiples of these

quarter wave section distances are chosen, and goes on to explain what he means by multiples of the distance.

Beginning at line 18, on page 2, he points out that in the case where the surge impedance is greater than the load impedance or load resistance, he may either connect [fol. 157] a capacity across the line in the first quarter wave length section, or an inductance across the line in the second quarter wave length section, or again, the capacity across the line in the third wave length section, and so on.

That description ends at page 2, line 40.

Then, beginning at line 44, on page 2, he points out that in the event that the surge impedance is less than the load resistance proper termination is had by connecting an inductance in the first quarter wave length section or a capacity in the second, or the inductance again in the third, and so forth.

That description carries on to line 63.

Immediately after he points out again that he prefers to connect the reactance as closely as possible to the load, so as to include a minimum section of the line between the reactance and the load. That, of course, gives the greatest length of matched line, high efficiency of line.

This new type of matching circuit in any one of the four cases to which I have referred, represented by the four lines in the tabulation at page 2, line 90, permits one to get the transmission line of unity power factor or electrically infinite length, which is generally described in the earlier patent, No. 1,623,996, but without having to use the type of matching transformer that was shown in that patent.

Those transformers are difficult and expensive to construct in such a way that they will give maximum coupling and also sufficient insulation for the high voltages that are common in the transmitting antenna systems; and also they are relatively difficult to adjust.

[fol. 158] The new idea set forth in this second Carter patent, of replacing the matching transformer by a part of the transmission line itself plus a simple capacity or inductance connected across that line at a proper distance back from the load, avoid those transformer difficulties, and it gives us in practice a very satisfactory structure.

In setting up a system using the matching arrangement of this second Carter patent, the transmission line is run directly from the source or the generator to the load or the antenna, and it is not necessary to disturb that line or to

modify it in any way in order to make the adjustments that one has to make so as to match the load resistance to the surge impedance of the line.

That simple procedure of connecting a reactance, either capacitive or inductive in any one of the quarter wave length sections that one may desire to choose, whichever is the most convenient, in accordance with the teaching of the Carter tabulation here, is in definite contrast to some of the earlier matching schemes, such as the transformers or the quarter wave length copper tubes with adjustable spacing that are used in some of the defendant's antenna systems.

For example, the copper tube type of adjustment requires that the tubes should be located so that the ends nearest to the antenna are at a point where maximum or minimum current would occur in the antenna wires before the tubes were adjusted, and it is hard to locate points of that kind before the system is completely connected.

If one inserts these tubes at the wrong point, then in order to move them either toward or away from the antenna, the wire must be cut and repaired correspondingly; [fol. 159] and the same sort of thing is necessary in connection with the transformer operation, although there you are not limited to the points of connection fixed by current maxima or minima.

Your Honor will doubtless appreciate that there is a real practical advantage in a structure where, after an antenna is built, one needs only to run an ordinary transmission line all the way from the generator to the antenna, and without having to consider while doing that what type of matching device you are going to use, or where you are going to locate it, or whether you have to build a house in which to put it, or any of those factors.

With Carter's matching system of this second patent, after the transmission line was put permanently into place, he made the desired adjustments simply by connecting across it at a convenient point, either a coil or a condenser, or a capacity or inductance, provided in some other way, and in that way the line from the transmitter to the far end of the antenna was, in effect, an unbroken and uniform conductor, extending all the way from the generator to the far distant end, and it did not have to be modified by the insertion of any apparatus for the attainment of the desired match.

I can summarize the disclosure of the second patent by saying that it is a practical circuit for matching the surge impedance of a transmission line, and the resistance of a load such as an antenna, and that it has advantages which can be tabulated as

[fol. 160] First, that no transformer, or other elements that are difficult to design for maximum effectiveness are required.

Second, that the circuits may be arranged so as not to use any element requiring protection from outdoor weather.

Third, that the transmission line may be initially run directly from the source to the load whatever the positions of either of those may be, and the matching adjustment then made without altering the line in any way.

Fourth, the adjustments that are made for the matching are comparatively quick and easy to find.

Fifth, once adjusted, the system maintains its characteristics stably and requires no attention.

And, of course, finally, the matching system is extremely simple and economical.

Q. 55. You stated that one of the advantages of the circuit arrangements of the second Carter patent was that the circuits might be arranged so as not to use any element requiring protection from outdoor weather. I show you Plaintiff's Exhibit 14 and ask you whether in the arrangement shown in that circuit there is any protection from the weather of the matching circuit?

A. Yes, the matching circuits are enclosed within the boxes that are indicated by the rectangular enclosures in Exhibit 14.

Q. 56. Will you now please refer to the first Lindenblad patent No. 1,884,006, and explain the disclosure of that patent with respect particularly to Figs. 1 and 2?

A. This patent discloses the structure of an improved directive antenna using a pair of long wires. It is prin-
[fol. 161] cipally concerned with the radiating antenna itself and does not relate specifically to the transmission lines.

The application was filed September 7, 1928, more than five years after the application date of the first Carter patent which I have discussed, and after a good deal of

work had been done in the development of short wave communication, but at a date earlier than the application for the second Carter patent, No. 1,909,610.

At the opening of the specification, Lindenblad points out that the invention relates to antennæ, and more particularly to directional antennæ for the propagation of reception of short wave signals.

In the second paragraph of this specification, he goes on to say that various forms of beam or projector antennas developed at prior dates are complicated, expensive to erect and to adjust, and that those prior art complicated antennas are structurally suitable only for use with the particular wave length for which each one was designed and built.

At lines 11 to 19, he points out that his new antenna is composed of simple linear conductors, and that it is in such form that a single antenna structure is suitable for use with any one of a considerable number of wave lengths.

In the third paragraph of the specification, beginning at line 25, Lindenblad describes the radiation from a single long linear or straight conductor, and by that he means a wire which is several wave lengths in length. He refers to the case when the wire is carrying standing waves.

Later in the specification, page 4, lines 120 to 122, he gives an example of such a long wire as one approximately eight [fol. 162] mean waves in length, that is to say, approximately eight wave lengths long.

I think that I have pointed out that a long wire is long when it is several wave lengths in length. That is, that the unit we must consider in connection with the description of long wires or long lines is the wave length and therefore that a single wire of a certain physical length in feet may either be long or short, depending upon the wave length at which it is used. For example, a 600 foot wire would be long for a wave length of 50 meters, because 50 meters is only about 150 or 160 feet, and there would be nearly four wave lengths on the wire. On the other hand, that same wire, if it were used at a wave length of 600 meters would be a short wire, because in that case, it would be only about one-third of a wave length long.

The Court: In other words, it is all relative?

The Witness: Yes, it is all relative, and unless we know the unit, we can not judge the length of the wire, knowing

the length of the wave length, we can tell, whether it is a fraction of a wave length long, and therefore a short wire, or several wave lengths long, and therefore a long wire, in the sense that we are using those words here.

When the energy of alternating currents is fed at one end of a wire, and is practically entirely abstracted or usefully used at the other end, or if the energy is used up along the length of the conductor, then there is no effective electrical discontinuity at the far end, and consequently there [fol. 163] is no reflection of energy from that far end back along the wire.

Under conditions of that sort, we say that the wire carries a traveling wave only and considers that the alternating current energy travels from the point where it was supplied toward the point where it is used up.

On the other hand, if there is a discontinuity—an electrical discontinuity—or an abrupt change in the electrical values at the remote end of the line, of the sort we have been considering, the energy that reaches that end of the line as a traveling wave is reflected and the reflected or returning energy or wave of energy, combines with the main wave, the outgoing wave, so as to produce standing waves along the line.

Now, similar conditions apply to these antenna wires. In the case of a wire several wave lengths long, and having its remote end disconnected from anything except a mechanical support—that is, electrically disconnected or insulated or open or free—all the terms being more or less the same,—the abrupt termination at that remote end causes almost complete reflection of the electrical energy reaching the remote end.

Therefore, the use of an open ended wire, a wire having an insulated end, favors the production on that wire of standing waves because of the substantial reflection that exists in such an abrupt termination.

Because the velocity or speed of the current wave traveling along such an open wire is about the same as the velocity of the radio wave in space, the number of complete standing waves on a wire is almost exactly the same as the length [fol. 164] of the wire divided by the wave length. In that way a single wire 200 meters long, about 650 feet long would have developed in it four standing waves of 50-meter wave length.

Q. 57. In the type of antennas and feeding systems that we have in this case, what is the type of wave that is desirable on the transmission line?

A. On the transmission, you are anxious to get the traveling wave, the wave which conveys the maximum power with the minimum voltage and current, and which is the result of minimum reflection or zero reflection at the end of the transmission line.

Q. 58. And in the antenna portion of the apparatus, what type of wave is desired there?

A. In the antenna portion, these antennas use standing waves, that is to say, there is large reflection at the end of the antennas and the antennas are tuned so that the waves build up in the standing wave form.

Q. 59. All right, will you please proceed?

A. Lindenblad, on the first page of the specification, beginning in the paragraph starting at line 25, points out that a single antenna wire of the sort I have been discussing, a linear conductor, which is long as compared to the working wave length, will not radiate wave energy in the direction of the wire axis; and also that in a plane perpendicular to the axis of the wire, the radiation is substantially, or even entirely, cancelled out; also that the principal radiation from such a wire is in a double hollow cone which has the wire as its axis.

That is illustrated in Fig. 2, and further described on the second page of the patent, beginning at line 77. Your Honor will recognize that this Fig. 2 is a diagrammatic [fol. 165] representation of the distribution of radiation, and may be compared to the sort of diagram we have already mentioned here.

The wire itself is represented by the vertical line 8 in Fig. 2, and a cross section of the radiation is represented by the two conical figures numbered 10 and 12, the lines of the lobes extending upwardly and downwardly and to the left and to the right, being again proportional to the intensity of the radiation in the particular direction from the center to any point on the lobe pattern itself.

The thing may be visualized by considering that a single long wire transmits its radiation principally along lines which form two conical surfaces, the axes of the cones being the same as the axis of the wire. In other words, Fig. 2, being a cross section, would be rotated around the wire in order to represent the complete conical pattern in space.

That contrasts, because of the action of the length of the wire, with the distribution of the radiation from a short one-half wave length wire, which is described at page 2, lines 71 to 76, and is illustrated in Fig. 1. There the radiation is in the form of an annulus or doughnut surrounding the wire, and extending in the direction or in the plane perpendicular to the wire itself.

I discussed what these radiation patterns meant the other day, and I think I used this drawing, Fig. 1, as an example. Those same considerations apply to other directive patterns or other patterns of radiation such as Fig. 2, and such others as we have spoken of.

Q. 60. Now, Lindenblad states, at page 1, lines 45 to 48, that the radiation from the simple long wire is wasteful [fol. 166] of energy, and one object of his invention is to reduce the conical radiation so that it will consist only of concentrated lobes having axes in one plane. Will you please explain how he accomplishes this object?

A. He gets that result by making his antenna of two parallel wires, each several wave lengths long and by applying the electrical power to those wires so as to excite them in phase opposition, which I will explain. He illustrates such two-wire antenna in Fig. 3. There the two wires are marked 14 and 15. The other ends are connected to the generator 20 so that the power is supplied to both of the wires.

The result of making such a structure is to concentrate the conical radiation illustrated by Fig. 2 into four directions which are indicated by the four lobes marked 30, 32, 34 and 36 in this Fig. 3.

Because of the co-operation of the two wires the radiation above and below their plane, so to speak,—imagining them to be horizontal,—is largely cancelled out, and the bulk of the radiation remains in the plane of the wires themselves, but in these four directions within that plane, the four directions being indicated by the four lobes to which I have referred.

Now, this matter of supplying power to the wires so as to excite them in phase opposition simply means that the voltages and currents at corresponding points on the two wires at any particular instant are opposite in polarity, that is to say, for example, when the end of wire 14 is

charged positively, then the end of wire 16 will be charged negatively, and so forth, for other corresponding points and instants of time.

[fol. 167] To determine that particular condition, one must look at corresponding points of wire and look at them at the same instant. If, then, they have opposed polarities, they are said to be excited in phase opposition.

The way that is done is by connecting each of the two wires to the ends of a transmission line, such as No. 24 in Fig. 3, and the wires from that to the opposite ends of the generator, such as 20, so that the two wires of the transmission line are oppositely charged at any instant, and consequently the two antenna wires, being directly connected to them, are oppositely charged at any instant. That causes the antenna wires to be, in the technical phrase, "excited in phase opposition".

Under those conditions, then, the currents and voltages in the two antenna wires are at opposite polarity at any instant, and that results in the condition that the standing waves developed in the wires, the standing waves along the wires, will have opposite polarity at any instant.

What I have said about the distribution of the radiation around such a two-wire arrangement is explained by Lindenblad in some detail at page 2, beginning at line 105, and carrying over to page 3, line 10. Briefly it is that the antenna does not radiate in a direction normally or perpendicular to its plane, but tends to concentrate the radiation mainly in its plane, which in the case of Fig. 3 is the plane of the paper. At that same part of the specification Lindenblad explains the desirability of using open-ended wires, that is to say, wires having free or insulated far ends, so as to develop standing waves most effectively.

[fol. 168] I think that summarizes what the patent has to say as to Fig. 3.

Q. 62. After that, Lindenblad states, commencing at line 62, on page 1, that, referring to the arrangement of Fig. 3, "This arrangement, too, is wasteful of energy, and it is a further object of my invention to strengthen the radiation in one pair of opposite critical directions, while weakening the radiation in the conjugate pair of opposite critical directions." Will you please explain how he accomplishes this further object?

A. He does that by relocating the two parallel wires with respect to each other, that is to say, in this case by stagger-

ing the two wires. Fig. 4 shows such an arrangement, and that is described at page 3, lines 11 to 43. The result of moving one wire forward along its length, so to speak, and in that way staggering the two wires with respect to each other is to suppress two of these lobes of radiation illustrated in Fig. 3, thus the lobes marked 34 and 46 are shown in Fig. 4 as having been substantially minimized or even cancelled out. They are shown by the very small lobes 34 and 36 in Fig. 4.

The act of suppressing those two tends to emphasize the two other lobes in the conjugate or opposite angle across the axis, and this is indicated by the larger extent of the lobes 30 and 32 in Fig. 4.

By staggering the wires, then, Lindenblad produced an antenna system in which the principal radiation is in two directions along a single line, as illustrated by those lobes 30 and 32, and such an antenna system is called a bi-directive or bi-directional system. This type of radiation, long wire radiation, is a directive front and back or bi-directive radiating system made up of two simple straight long wires [fol. 169] having their remote ends open and excited as I have described in phase opposition.

Q. 63. Lindenblad then states at line 89 of page 1 that "the radiation has so far been reduced to a bi-directional radiation, and a further object of my invention is to make it unidirective". Will you please explain how he accomplishes that further object?

A. He points out immediately following the portion that you read that he provides another pair of simple linear conductors, and he describes that in greater detail at page 3, beginning at line 43, with reference to Fig. 5, which illustrates an arrangement of this kind.

In Fig. 5 there is a second pair of wires arranged beside the first pair, the first pair corresponding to the pair of wires in Fig. 4. The distance between the two pairs is an odd number of quarter wave lengths when measured along the direction of principal radiation. That is shown in Fig. 5 where the lobe 30 represents the direction of principal radiation and the distance between the two aerials is marked (2n plus 1) lambda over 4. That is simply the mathematical statement that the distance shall be an odd number of quarter wave lengths.

Lindenblad explains that the second pair of wires, like the first pair, is excited in phase opposition, that is, the voltages of each wire of the pair are opposite at any instant at corresponding points. But the currents in the second pair taken as a pair are displaced from the currents in the first pair in phase or in time by a quarter of a period, that is to say, by the time of a quarter of a cycle, which is usually spoken of as a 90-degree displacement.

[fol. 170] That double pair arrangement, as is indicated in Fig. 5, results in still further concentration of the radiating power into the single lobe marked 30 by the almost complete suppression or cancellation of radiation in the opposite direction represented by the backward lobe 32 in Fig. 4.

A radiating system of this sort, where the principal radiation is concentrated in one direction from the antenna (and of course we are speaking of the horizontal plane, it is a horizontal antenna), is called a unidirective or unidirectional antenna. Therefore, in Fig. 5 Lindenblad shows a unidirective radiating system which consists only of long wires in pairs, the wires of each pair being open-ended and carrying standing waves. The currents in each wire are produced by a generator which drives the wire of each pair in phase opposition, as I have described, and the two pairs of wires are so excited that one has currents one-quarter of a period or 90 degrees out of phase with the other pair.

That results in this unidirective system, and in my earlier testimony I pointed out the practical value of concentrating the radiation in a given direction when one is concerned with a point-to-point communication system.

Q. 64. Mr. Hogan, will you please summarize what you consider to be the basic features of the disclosure of this patent?

A. The basic features of this Lindenblad disclosure include a pair of wires, a pair of long wires excited in phase opposition and carrying standing waves, and the arrangement of those wires so as to concentrate the principal radiation in the plane of the wires.

Then he shows a modification which comprises reloca-
[fol. 171] tion of the two wires one with respect to the other so that the lobes of radiation within the plane are combined in order to give a bi-directive radiating system.

Then as a further improvement, giving increased directivity, he describes the use of a second pair of bi-directive wires, each of them parallel to the similar wire in the first pair, and the two pairs being combined so as to produce a unidirective or single directional system.

I think that summarizes the basic features with which we are here concerned.

Q. 65. Now will you please state some of the practical advantages of the system shown and described in this patent?

A. First, the wire arrangement is simple and economical, both to construct and to maintain.

Secondly, the remote ends of the antenna wires are open or insulated and require no terminating apparatus connected to them.

Third, either the bi-directive or the unidirective radiation that I have discussed is obtained by means of structures that are less complicated and less expensive than the bi-directive or unidirective antennas that had been in use.

Fourth, the efficiency of the antenna system can be maintained without difficulty when the operating wave length is altered and without rebuilding the antenna, and

Fifth, the simple long wire antenna of this character has a high radiation efficiency, and by that I mean that a large percentage of the power applied to the antenna is radiated in the form of waves. In an antenna of this sort, radiation efficiency of the order of 90 per cent. or more is customary, [fol. 172] whereas in antennas like the Model A, the curtain type antenna, the complicated network of which we have spoken, an antenna efficiency of 50 per cent. or thereabouts, is about all to be expected.

I think that summarizes the advantages, that appeal to me, at least.

Q. 66. Now will you please refer to the second Lindenblad patent in suit No. 1,927,522, and explain the disclosure of that patent, particularly with respect to Fig. 2?

A. Like the first Lindenblad patent, this second Lindenblad patent No. 1,927,522 also relates principally to the radiating antenna itself, rather than to the transmission line that may be used to supply power from the generator to the radiating system.

The application for this second Lindenblad patent was filed December 24, 1928, which was about three months after the date of the application that resulted in the patent No. 1,884,006, which I have just considered.

The disclosure of Lindenblad's second patent represents another step of the RCA engineering group in simplifying the complicated and expensive directive antennas that are typified by the British beam or Model A, or other curtain types to which I have referred rather briefly, but which Mr. Hansell described in greater detail.

In Fig. 2 of this patent Lindenblad shows a V-shaped antenna. It is made up of two long open-ended wires that are excited in phase opposition and are supported so as to diverge from one another.

Those are the wires 2 and 4 of Fig. 2, their open ends being shown at 12 and 14 in the figure.

[fol. 173] Beginning at line 29 of page 1 of the specification, Lindenblad explains that an arrangement of this kind produces predominant radiation in the direction of the axis of the pair of conductors, and he has, earlier in the specification, at line 10, referred to the antenna as an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency.

He points out, at lines 32 to 35, that in such an antenna reflections will cause a standing wave instead of a traveling wave, and that that will result in radiation sidewise from the antenna, thus there may be radiation not entirely along the axis of the antenna system.

However, in spite of such sidewise radiation he states that the radiation in the preferred direction is considerably greater than that which is obtainable from a simple doublet or a half wave di-pole, for example.

Now we know from later study of antennas of this type that if one sets up a pair of wires, each pair five to ten wave lengths long, and if one spaces the open ends of those wires by about one-fifth of their length, there will be produced a received signal in the desired direction of transmission that is as much as three times as powerful as one would get from the same amount of power applied to a half wave di-pole antenna.

Those dimensions of five to ten wave lengths long and having a spacing at the open end in the neighborhood of one-fifth of the wire length, are suggested by Lindenblad at page 2 of the specification, beginning at line 116.

This Fig. 2, to which I have been referring, shows schematically or diagramatically by means of a rectangle marked [fol. 174] 16 and having the legend, "Impedance Matching Device", that the wires may be used with impedance matching of the sort that I have discussed in connection with the earlier Carter patents.

Lindenblad points out beginning at line 116 of page 1, that reflection may be neglected if the transmission line is short; but if the transmission line is long, and the antenna is relatively small, so that only a small portion of energy is radiated, it may prove desirable to employ an impedance matching device between the transmission line and the antenna as is indicated by the impedance matching unit 16 shown in Fig. 2.

I have read the portion of the specification carrying over to line 3 of page 2.

Thus, if the antenna is not so long that the energy is largely or almost entirely radiated from it, without reflection from the ends, the impedance matching device may be desirable.

The principal advantages of this Lindenblad diverging long wire antenna are its simplicity, its cheapness, its operativeness over a considerable range of frequencies, and its ease of erection, maintenance and adjustment. As he describes it in this patent, it had not attained its final form or its most efficient form, and further theoretical work and experimental development were necessary before the modern V type antenna was produced.

Lindenblad recognized that his directive antenna wasted power due to radiation in undesired directions, and he proposed to remedy that, as he says, at page 1, line 38, by "as a refinement reducing the standing waves in the wires". Reduction of standing waves would reduce sidewise radia- [fol. 175] tion, but not sufficiently to improve the antenna efficiency, or rather the antenna directivity, because we are concerned with directive efficiency at this point, sufficiently to make the radiating system meet the rigid requirements of commercial service.

It remained for Carter to discover that this reduction of undesired sidewise radiation could be obtained more effectively, by taking advantage of a new co-relation between the length of wires and the length of waves, and the angle between the diverging wires. I will explain that in more

detail in connection with the third Carter patent. Nevertheless, the V antenna in its most highly developed form and as it is used, both by the defendant at Sayville and by the RCA Communications organization at Rocky Point and elsewhere, does have these features and advantages, which I have described in connection with the disclosure of the second Lindenblad patent, 1,927,522.

Q. 67. Have you had prepared under your direction and supervision a scale model of the defendant's antenna No. 8, as described in Plaintiff's Exhibit 7 in this case?

A. Yes.

Q. 68. And this apparatus, one end of which stands on one table and the other ends stand on another table, is that the apparatus?

A. Yes, that is the model.

Q. 69. Except that the transmission line is not connected to it at the present moment?

A. Only the end of the transmission line, nearest the apex of the antenna is on the model as it is now set up; the full transmission line would run off some distance to the right.

Mr. Blackmar: I offer the model in evidence.

[fol. 176] (Marked Plaintiff's Exhibit 29 in evidence.)

Q. 70. Mr. Hogan, will you please refer to the third Carter patent in suit, No. 1,974,387, and state first, in general, what it relates to?

A. This patent, which we are calling the third Carter patent, shows a new antenna system, which is the modern and highly efficient form of V antenna. It involves the latest of these improvements worked out by the RCA engineering group, and uses the basic disclosures of both of the earlier Lindenblad patents. The application for this patent was filed June 11, 1930, about a year and a half later than the application for the Lindenblad diverging wire antenna, patent No. 1,927,522.

Carter's specification in its opening paragraph states the primary object of his invention to be the provision of a simplified and highly efficient antenna system utilizing standing wave phenomena.

Q. 71. At lines 15 and 16 on page 1, Carter states that the present invention makes use of certain phenomena which

he has previously described as known at that time. Will you please explain these phenomena, and how he utilizes them, referring particularly to Figs. 2 and 3, and if you desire, to the model Plaintiff's Exhibit 29, and also state what he accomplished by the utilization of these phenomena?

A. The phenomena to which he referred are those relating to the symmetrical, double cone of radiation from a single long wire, which are illustrated in figs. 1-a and 1-b of this third Carter patent.

This action of a single wire was explained by Lindenblad in patent 1,884,006. Fig. 2 of that Lindenblad patent resem- [fol. 177] bles closely this Fig. 1-A, of the third Carter patent. Both of those figures show the principal cones of radiation around a single long wire of that kind.

Beginning at line 17, on page 1, Carter describes his antenna in its most simple aspect, as being made up of two relatively long, open ended wires, excited in phase opposition, carrying standing waves throughout their lengths, and being placed at an angle to each other in a single plane.

He further points out that the angle from each wire to the bisector of the angle between the two wires, corresponds generally to the angle of the principal cone of radiation of one of the wires.

With a V arrangement of that kind, the principal radiation of a pair of wires then takes place bi-directionally along the line of the bisector and principally in the plane of the wires.

Figs. 2-A and 2-B and 2-C of the patent which are described further at page 2, beginning line 29, illustrate a structure of this kind.

It may be easier to visualize this arrangement by referring to the model, Exhibit 29, because that is built in three dimensions, rather than simply being a drawing on a sheet of paper. This simple V antenna of Figs. 2-A, 2-B and 2-C is represented in the model by either one of the two V's.

The wires are long, they are energized in phase opposition by their connection to the transmission line and generator, as I explained in connection with the first Lindenblad patent. They have standing waves as favored by the use of open-ended or insulated wires, unconnected to anything, that is the far ends of the antenna, and they are in a single [fol. 178] plane, the two wires of each V, and located at an

angle such that the principal radiation is along the bisector of the V.

Thus Carter utilized Lindenblad's diverging wire antenna, and further discovered that it was of great importance practically to place the wires of the antenna at least approximately at a referred angle to each other, and further that that angle depended both upon the wave length used, and the physical length of the wires comprising the V.

Carter found that by using that preferred relation between those three factors, wave length, the wire length and the angle between the wires, that with standing waves on the wires, it was possible to obtain unexpectedly high increases of signal power, due to the directivity of the system.

For example, with Carter's arrangement a single V having wires from five to ten wave lengths long, gave signal multiplications of from 6 times up to about 12 times that which would be had from the standard di-pole using the same amount of power.

Q. 72. At what point?

A. At the desired receiving point.

That very substantial and valuable increase in effectiveness came about because of a surprisingly great reinforcement of the signal transmitted in the direction of the bisector, which was accomplished by a reduction of wasted radiation, and that reduction, in turn, being accomplished by a surprisingly great cancellation in all directions both horizontally and vertically around the antenna system.

Carter's rule corelating the angle represented by Alpha in Figs. 2-A and 2-B of the third Carter patent, corelating [fol. 179] that angle with the wave length used, and with the length of the wire, taught how this principal radiation from the long diverging-wire standing-wave antenna could be concentrated not only in the plane of the wires, as occurred with the Lindenblad arrangement, but also still more effectively into a bi-directive beam within that plane.

In that way, Carter's directive antenna obtained the high efficiency and directivity that he refers to at line 3 and lines 21 and 22 of page 1 of the specification.

Now, on page 2 of this third Carter patent beginning at line 47 and continuing to line 77 or 78, Carter explains how the preferred angle for a given wave length and given length of wire may be found from the equations that are printed at lines 60 and 70 approximately.

The first of those equations applies when the side wire of the V has a length which is equal to an odd number of half wave lengths, as is stated at line 57, and the second equation applies for side wires, having an even number of half wave lengths in their total length.

Carter also points out (and for that, I refer to page 1, lines 29, and following), that he has found the preferred angle for a pair of wires of any specified finite length in relation to the wave length, when they carry standing waves. In that way he explains not only the use of V antennas whose side wires are equal in length to any part and approximately an exact multiple of the half wave length, either even or odd, but also the use of wire length of any intermediate value between the even and odd number of half wave lengths. [fol. 180] At page 2, line 83, he gives the equation for determining the preferred angle for any particular wire length, and Fig. 12 of the patent is a chart from which it is easy to read the preferred angle for any length of side wire, from one to 14 wave lengths, and, of course, that more than covers the range of lengths that is in common use.

For example, if the length of one wire of the V, as stated along the bottom of Fig. 12, is six wave lengths, one may run up the verticle line above the No. 6, to the intersection with the curve, and then across to the left, where we find that 20 degrees represents the angle Alpha, or half the angle between the wires, and therefore the total included angle represented and preferred for a wire length of six wave lengths would be twice that or 40 degrees.

The simple form of the single V diagrammatically illustrated in Figs. 2-A, 2-B and 2-C, then comprises the two radiating wires marked A and B, each one of them located approximately at the preferred angle, from the bisector which is indicated by the lines X-X of these figures. The separated ends, the remote ends of those wires are insulated or free or open, as I have said, so as to promote standing waves on the antenna wires, and the ends of the wires at the apex of the V are excited through the transmission line in phase opposition.

Q. 73. Now, will you please take up Fig. 4 of this patent, and explain the disclosure of the patent with respect to it?

A. Yes. Fig. 4 is a rather pictorial illustration of a practical application of the arrangement of Fig. 2 of the patent. The V wires in Fig. 4 are marked A and B, and

[fol. 181] the connections to the transmission line 24 are marked 26. In Fig. 4, in the arrangement shown there are two V's one arranged above the other, the upper one being marked A-B, and the lower one A'-B'.

That particular arrangement results in a further concentration of the waves more nearly into a single horizontal plane, as Carter explains at page 3, line 24, but double layer V's of that kind are not used by the defendant, so far as I know.

Even though this be a two-story or double layer V in Fig. 4, it is a single V antenna, from the view-point of its horizontal directivity, which is what we are concerned with at the moment, because the radiation from an arrangement like that of Fig. 4 is a bi-directive. Such bi-directive radiation is shown in Fig. 3 of the patent, and that applies to single V's whether they are in the simple form of Fig. 2 as represented by one of the V's of the model, Exhibit 29, or whether they are represented by the vertically-disposed pair form of Fig. 4,

In other words, the simple antenna element of Fig. 2-A or 2-B or 2-C, or the simple V corresponding to one of the V's in the model, or the two-story V of Fig. 4 has bi-directive radiation, of the sort generally represented by Fig. 3 of the patent.

Q. 74. At page 1, lines 43 to 44, Carter states that "A further object of the present invention therefore is to provide a unidirectional arrangement." Will you please state how he accomplishes this?

A. Yes. Carter does that by setting up a second similar pair of V wires, the individual wires of the second V being parallel to the corresponding individual wires of the first V, and he sets up this second V, in a position which is determined by measuring a distance equal to an odd number [fol. 182] of quarter wave lengths along the bisector line. Fig. 5 of the patent shows a double V antenna giving unidirective radiation and made up in that way. The two horizontally separated V's in Fig. 5, one, that is the rear, being marked a and b, and that to the right being marked A and B, are said to be separated by a distance of 2¼ wave lengths, which is nine quarter wave lengths, or an example of the odd quarter wave length spacing.

The model also represents two such parallel V's arranged with an odd quarter wave spacing, in this instance, the

distance being three-quarters of a wave length along the line of the bisector.

Fig. 5 of the patent shows a two-story arrangement, each V having below it a second V, for vertical reinforcement, as I explained in connection with Fig. 4, but so far as I know that second story is not used in either the single or the double V's by the defendant.

There is another variation of the double V arrangement shown in Fig. 11, which is practically the same as Fig. 5, except that each of the V's has four stories, located vertically, so as to give still further concentration of the radiation with respect to the vertical plane.

Any one of these double V arrangements, that of Fig. 11, that of Fig. 5, or that of the model, has generally the radiation pattern in the horizontal plane which is shown by Fig. 6 of the patent. That is to say, all of them give primarily unidirective radiation along the bisector line.

Similarly the use of two V's in this way, so that the radiation in the desired direction is increased and that in the rearward direction decreased, results in twice the power [fol. 183] gain for signals in the desired direction of principal radiation than would be had from a corresponding single V, having the same dimensions.

That doubling of the power gain takes place whether one compares two single V's as in the Model, Exhibit 29, or two two-story V's as illustrated in Figs. 4 and 5 of the patent. Fig. 4 is a two-story single V, and Fig. 5 a double two-story V. What I mean is, if the dimensions of the V's are the same, Fig. 5 will give double the gain of Fig. 4, even though two-story elements are considered, just as, in the case of the model, doubling the gain is had in the preferred direction from two single V's as against one V. We have nothing to compare Fig. 11 with in the way of a single V, but we could imagine a four-story single V, and in that case Fig. 11 would give double the gain of the four-story single V where the two had the same fundamental dimensions.

Beginning at line 68 on page 3 of the specification, and further beginning at line 9 on page 4, the first reference being with regard to Fig. 5 and the second with regard to Fig. 11, Carter gives further details of these double V arrangements and includes an explanation of the preferred phase or excitation difference of 90 degrees as corresponding to an odd number of quarter periods.

The preferred spacing for the two sections, which are often called the antenna and the reflector, is given as two and one-quarter wave lengths when the wires are from six to twelve wave lengths in length.

It is also pointed out that where wires are shorter, say, from three to four wave lengths in length, the spacing be- [fol. 184] tween the pairs of wires along the bisector may be one and one-quarter wave lengths or less.

Q. 76. Will you please refer to line 125 of page 3 of the patent and explain that mathematical expression that occurs there, and its application to these antennas?

A. That is a general statement of the phase difference between the units or sections for the preferred condition, and simply states that the spacing measured in wave lengths should correspond with the phase difference in periods. For example, if the spacing is one-quarter of a wave length, the phase difference should be 90 degrees, and as the spacing is increased to three-quarters or five-quarters, the preferred phase relation is shown to be either plus or minus 90 degrees, which amounts to the same thing because it is a relative phase difference. The expression at line 125 is used in connection with Fig. 9 of the patent, but is sufficiently broad mathematically speaking to apply to the general arrangements we have been discussing.

Fig. 9 is an arrangement that I understand is not involved here.

I might also point out that Carter says that following this rule gives the concentrated unidirectional propagation in either direction, depending on whether the current in one unit leads or lags that in the other, that is to say, whether the relative phase of the currents is plus or minus 90 degrees, as compared to the spacing.

Q. 77. So that, according to each of those arrangements, the unidirective radiation from an antenna of this type may be either from the apex of the antenna toward the open ends in the direction of the bisector or in the direction of the [fol. 185] bisector from the open ends through the apices?

A. Yes; you have complete control of that 180-degree reversibility of direction by changing the relation between the feeding of the two wires. For example, by transposing the transmission line between the first pair and the second pair, or by feeding at the inside pair first, instead of at the outside pair.

Q. 78. Now will you please explain the methods of tuning these antennas and matching the load resistances to the surge impedance of the transmission lines, as shown, for example, in Fig. 2C of this patent, and in other figures?

A. Fig. 2C shows a U loop composed of the conductors extending from 16 to the cross bar 14, and having taps at the points 18. The arrangement is suitable for tuning the antenna system and matching its impedance to the surge impedance of the transmission line which supplies the radiating system with power.

The arrangement is described and its construction and adjustments pointed out at page 2, beginning at line 116 and running on down through the next few paragraphs.

Briefly, in order to tune an antenna system composed of the wires AB, the total effective or electrical length of the two radiating wires plus whatever is connected to the apex end is made equal to an odd number of half-wave lengths, or to say it in another way, each side is made equal in electrical length to an odd number of quarter-wave lengths.

Carter points out, at page 3, beginning at line 8, that it is the length of the V-shaped radiating part of the antenna [fol. 186] system, not including the length of the wires in the loop or tuning means or transmission line, which is to be used in applying the rule or the chart of Fig. 12 to determine the preferred angle.

When the antenna is tuned by adjustment of the connections 14 governing the position of the cross connector and of the taps 18 in Fig. 2C so as to get the proper lengths in the different parts of the system, then the inductance and capacity effects are balanced out and the antenna acts at the points 18 as a pure resistance load. The value of that resistance load is matched to the surge impedance of the transmission line by the tapping of the transmission line into the connections to the radiating system at the proper points which are marked 18 in this Fig. 2C.

That method of tuning and matching is generally similar to the arrangement of Fig. 3 of the second Carter patent No. 1,909,610. The inductance 12 in the figure of the second Carter patent is replaced here by the equivalent inductance of the loop ending in the cross bar 12 of the third patent.

A short loop of that kind constitutes an inductance made up of a relatively large half turn of wire instead of one

made up in the more concentrated form of a coil having relatively small turns.

Q. 79. Now will you please refer to Fig. 7 of this patent and briefly point out what it means?

A. Yes.

Fig. 7 shows the power distribution in the vertical plane of such a horizontal V antenna without considering any effect due to ground. That vertical distribution is a pattern [fol. 187] which is made up in exactly the same way as the horizontal power distribution patterns that I have already described, as for example, Figs. 3 and 6, but instead of showing the horizontal directivity, which is the thing that determines in what geographical direction the signal is projected, this Fig. 7 illustrates the vertical directivity or directivity as referring to a vertical plane.

It has significance in connection with the efficiency produced by concentration, because within limits the sharper the concentration is in the vertical plane the more power is available for projection in the desired direction.

In the operation of a double V antenna such as we have represented by Model, Exhibit 29, the principal radiation of the antenna itself is in the geometric line of the bisector, that is to say, a horizontal beam is produced in so far as the cooperation of the antenna elements themselves are concerned. If a pair of V's of that kind were in space so that no conducting bodies were in their neighborhood to interfere with the direction of propagation, the energy would be concentrated along the geometric line of the bisector, speaking both vertically and horizontally. In practical use the antennas are set up on poles, usually about 80 feet high. Carter says at page 3, lines 58 and 59, that 80-foot poles or masts may be used to support the wires, and that is a common length. In that case, with the range of wave lengths that is common in short-wave transmission over great distances, the wires are, generally speaking, from three-quarters of a wave length to a little over one wave length above the ground. In a case of that kind, if one considers [fol. 188] distances a little way beyond the antenna itself and in the direction of propagation, it is not hard to see that following a diagram such as that of Fig. 7, some energy is projected downward to the ground, not directly along the line of the bisector, the geometric line of it. That energy going down from the end of the antenna is reflected from

the ground at an equal angle, and depending upon the character of the ground its phase is changed. The reflected energy combines with the energy radiated from the antenna itself and goes off into space, and the practical result of a set-up of this kind is that the beam from the antenna, instead of being projected along the geometric line, is actually tilted up at some distance from the antenna.

That, in practice, is a very good thing for these short wave lengths, because, in the first place, it has no effect on the horizontal directivity with which we are concerned, or the thing that makes the signal go to San Francisco, or something of that kind; and in addition to having no adverse effect upon the important horizontal directivity, it takes greater advantage of one of the most peculiar things about short-wave transmission, namely, it projects the waves up at an angle which is of reasonable value for their reflection down again from what we call the Heaviside layer in the upper spaces, perhaps 100 or 120 miles above the earth's surface, it reflects them down from that layer onto the receiving point; in other words, the effect of each of those conducting or partially conducting bodies, if we may call the Heaviside layer a body, is to change the direction of waves, and at a great distance one would imagine if he didn't know better that the received waves were coming [fol. 189] down from the heavens above instead of from a point on the earth's surface.

I think that that is all that follows from the showing of Fig. 7 and that we need to consider here, the important thing being to bear in mind that there is no effect of this vertical distribution upon the horizontal directivity, practically speaking, and that the pattern of Fig. 7 in the vertical plane, with ground effect neglected, does not represent the case where reflection from the ground beyond the end of the antenna causes a reinforcement of reflected and direct waves from the antenna so as to give a beam tilted upwards at perhaps 10 degrees instead of along the geometric line of the bisector.

Q. 80. Mr. Hogan, if the principal radiation were along the geometric line of the bisector, what would be the effect with respect to the ability to receive that at a distance away from the antenna in view of the curvature of the earth?

A. You would have to hope that enough energy would reach the Heaviside layer at a very great distance measured practically tangentially to the earth's surface at the point of origin for reflection down to your distant station. What would occur, I cannot say.

Q. 81. Mr. Hogan, will you please state some of the practical advantages of the type of antenna described in this patent?

A. First, the exceptionally high directivity per unit of the antenna system; second, its low cost of erection and maintenance; third, its simplicity and stability of adjustment; fourth, the fact that it utilizes standing waves effectively and that there is no need to minimize them either by having [fol. 190] exceptionally great length or by using terminal resistors; fifth, its adaptability to successful use with a wide range of lengths of wire and lengths of wave; sixth, its high radiation efficiency, which is usually 90 per cent or 95 per cent, or even more; and seventh, that if the side wires are longer than about six wave lengths in length, it has a relatively high directive efficiency for a considerable range of wave lengths in any one structure, that is to say, that the preferred angle becomes less critical for the longer wires.

I think those are the principal features.

Q. 82. Have you marked a copy of Plaintiff's Exhibit 23, the map of the Sayville station, with the numbers of the antennas as those antennas are identified in the stipulation?

A. Yes; in addition to the antenna numbers, I have also placed on the map the identifying call letters of the transmitters used with these antennas. I might point out that in the case of antennas Nos. 2 and 3 I have put down two call letters because those antennas are described in two forms, first, as originally built, and second, as rebuilt. The upper call letter in each case corresponds to the original use and the lower one to the use as rebuilt.

Mr. Blackmar: I offer that in evidence and suggest that it be marked Exhibit 23A.

(Marked Plaintiff's Exhibit 23A in evidence.)

Q. 84. Mr. Hogan, will you please describe generally this Defendant's antenna No. 2, in its original form, as covered in the stipulated description and the drawing annexed thereto, of which the chart now before you is a copy?

[fol. 191] A. At the time the suit was filed, the No. 2 antenna located north of the tall tower and buildings in the center of the property, was, as is shown by the sketch attached to Exhibit 10. Dimensions are given in part on the drawing, and in further detail in the tabulation, Exhibit 13.

The supporting poles and insulators and such details of structure are not illustrated in this chart, but only the radiating wires of the single V, which extend a distance of 517 feet from the open ends A and B to the apex C and D.

The angle included between the wires is shown on the chart as 35 degrees. The two wires are in a horizontal plane, which it is difficult to see from the drawings, the arrangement being like one of the pairs in the model, Exhibit 29.

The fact that three points of the V system are each indicated as 80 feet above ground is perhaps enough to define that horizontal placing.

The drawing shows also the transmission line which runs from the antenna downward and then more or less horizontally a distance of about 750 feet from the bend at the point IJ to the transmitter house, and vertically a distance of 67 feet, according to Exhibit 13, from the bend IJ to the antenna apex CD.

At the time the suit was begun this antenna was being used with a transmitter using the call letters WML, which are shown at the top of the chart, and a wave frequency of 14,740 kilocycles, which corresponds to a wave length of 20.35 meters, or only a little over 66 feet for a complete wave in space.

One of its destinations, according to Exhibit 10 was Vienna, Austria. The great circle bearing of Vienna from [fol. 192] Sayville is 49.74 degrees east of true north, and by that, of course, we mean simply the bearing measured with true north as zero degrees, and then rotated 49 odd degrees in the easterly direction.

That same bearing system is used, even though one goes all the way around to 280 degrees or to 300 degrees east of north. While smaller numbers would be involved if we went west of north, it is easier to have uniform numbers for reference.

The direction of the bisector of the antenna, which is called its directivity, and which defines the horizontal di-

rection in which the maximum radiation occurs when taken from the center of the antenna towards the apex, that is to say, to the left in the diagram, is 49.75 degrees east of true north, almost exactly that of the Vienna Great Circle bearing.

The antenna is also referred to in the stipulated description, Exhibit 10, as having been used for sending messages to Copenhagen, which has a bearing 43.36 degrees, to Budapest, the bearing of which is 49.52 degrees east of north, and Vatican City, the bearing of which is 57.9 degrees east of north.

The tabulation, Exhibit 13, also part of the stipulation, is arranged on two sheets in columns, one column corresponding to each antenna, and by reference to that and to this chart, one can find in the second column all the principal dimensions of the No. 2 original antenna, including call letters, wave length, destinations, and bearings, the angle east of north of directivity, and the mechanical dimensions and arrangements.

The tabulation gives the same data so far as it is known [fol. 193] for all eleven antennas, and the two additional forms of antennas, 2 and 3 rebuilt. The original antenna No. 2, like all of these V antennas, was to be supplied with high frequency power at its apex CD, because the radiating system begins there, and extends to the open ends AB.

CD is at the total distance of about 819 feet from the transmitter, measured along the transmission line, and that distance corresponds to something over 12 wave lengths from the power house, where the high frequency electrical power is generated, or the transmitter proper is located.

That distance from the transmitter to the apex of the antenna was, of course, bridged by the transmission line as shown in this Exhibit 10 drawing.

The stipulated description, Exhibit 10, states that the loop circuit KMNL was so adjusted when the antenna system was installed that an approximate impedance match was provided at the pair of points KL along the transmission line, whereby the energy was efficiently transferred across that pair of points, and reflection from there towards the transmitter was reduced.

That means that the effective resistance of the antenna system, taken in connection with the section of the transmission line from KL up to CD and with the loop KMNL has been made so that at the points KL it was equal within

practical limits to the surge impedance of the transmission line, from the transmitter to the points KL.

If that were not so, there would be an equivalent of an electrical discontinuity KL, and the energy would not be efficiently transferred across those points into the antenna [fol. 194] and, consequently, the wave energy would be reflected towards the transmitter, and therefore the stipulation, or rather, the description, Exhibit 10 attached to the stipulation, describes that there has been made the adjustment necessary to attain the condition described in the first Carter patent, in which reflection on the transmission line is so minimized as to make it substantially of electrically infinite length in the way that phrase is used in the patent; that is to say, to make it of the high efficiency which is desired, and which I explained in discussing the patent.

Referring to Fig. 1 of the patent, the generator 14 in the patent drawing, and the transformer 13-12, together, correspond generally with the transmitter in the drawing of Exhibit 10.

The two wire transmission line which has the reference number 10, in Fig. 1 of the patent, corresponds to the two wire transmission line extending from the transmitter to the apex points CD, by way of the match points KL in the drawing of antenna No. 2—original.

The impedance matching transformer, marked 11 and 2 in Fig. 1 of the patent corresponds in function to the impedance matching circuit KMNL and KL to CD in the drawing of antenna No. 2. And the antenna 1 and the ground 6 correspond in their connections in the patent, with the radiating wires AC and BD of the antenna drawing.

I might point out that although the electrical distance from the transmitter to the antenna apex was about twelve wave lengths in the original antenna No. 2, the distance from the transmitter to the match point KL is something less than that, being set back by the 67-foot riser and about [fol. 195] 30 feet horizontal distance, so that the distance from KL to the transmitter is about 720 feet or nearly 11 wave lengths from the transmitter.

Q. 87. Will you explain how the impedance match is obtained in this particular antenna, and compare the impedance matching circuits with those described in the second Carter patent, Plaintiff's Exhibit 2?

A. Generally speaking, the way the impedance match that I have described was attained or provided so as to

get the high efficiency transmitting line was by adjusting the position and the length of the wires KM and LN, and the position of the cross connection MN as described in the stipulated exhibit 10.

The distance from CD by the way of IJ to the point KL, or, in other words, the position of KL along the transmission line determines the length of the transmission line section from KL to the apex of the antenna at CD, and the half turn loop KMNL provides a shunting reactance across those points of the transmission line, and the amount and character of that shunting reactance is determined by the position of the cross connection MN along the side wires of those extensions from the transmission line.

In this case the reactance at the point KL provided by the loop KMNL is an inductive reactance. In this antenna No. 2 the transmission line has uniform characteristics all the way from the transmitter to the apex point CD. And if the system were left with only that line as initially run, it would not be matched, the transmission line would not have the high efficiency resulting from a reduction of standing waves upon the transmission line.

[fol. 196] The antenna would not even be tuned and, of course, its load resistance would not be the same as the surge impedance of the transmission line. That is saying, perhaps, the same thing in another way, but we have three or four ways of looking at this final, this same final effect.

The surge impedance of this line is about 600 ohms, and that results from the fact that the transmission line is made up of No. 6 wires, spaced 12 inches apart in accordance with the stipulated description. The load resistance of an antenna like this No. 2 original form antenna might be anything from a few hundred ohms up to several thousand ohms for the wave length that is being used, and how much that resistance component or effective resistance would amount to, would depend upon at what point along the antenna wires (or where the standing waves exist) one made the measurement.

As a general rule, the minimum value of resistance occurs at points that are quite near to an odd number of quarter wave lengths from the remote or open antenna ends, and the high values of resistance come at points that are close to an even number of quarter wave lengths from the open ends.

Now, in this instance, we have a distance of 517 feet from AB to CD, that is to say, the length of the side wire, and that is within a few inches of seven and three-quarter wave lengths, or 31 quarter wave lengths, that distance for that 66.77 feet wave, I think, being 517.39 feet. Those points CD, therefore, are located substantially at an odd number of quarter wave lengths, 31, from the ends of the antennas, [fol. 197] the open ends of the antennas; and therefore the antenna resistance at the points CD is of the order of 100 or 200 ohms, the lower values.

Consequently, it is considerably lower than the surge impedance of 600 ohms, that is characteristic of the transmission line.

Now, that condition where the load resistance is less than the surge impedance, corresponds to either case 1 or case 3 of the tabulation in the second Carter patent 1,909,610.

For case 1, capacity would be used across the line, and in case 3 inductance would be used across the line. Here the defendant has used an inductive loop across the line, and consequently the situation corresponds to case 3 of the tabulation at page 2 of the Carter patent, where he points out that the inductive reactance in case 3, should be connected across the transmission line at a point which would provide a line section length, that is the length between KL and CD in this case, which is greater than one quarter but less than one half wave length, or equivalently, as he pointed out, in an even numbered quarter wave length section of the transmission line, measured back from the load to the transmitter.

I have made a more detailed chart of this matching system for original antenna No. 2, which shows that the distance between CD, the apex, and KL, the point of connecting the inductive reactance, being 97 feet in length, comes more than one and a quarter but less than one and a half wave lengths from the apex, so that the points K and L are in the sixth quarter wave section measured toward the transmitter from the point CD.

[fol. 198] This diagram is, so to speak, an enlargement of the central portion of the drawing of Exhibit 10, but is all laid out in one plane, so as to make the relative dimensions easier to compare.

The corresponding points are lettered in the same way. For example, the apex of the V section is marked CD, points IJ, 67 feet from CD and 37 feet from KL, are marked along

the horizontal lines and KL and the loop itself are also shown.

That of the load resistance is less than the surge impedance of the line and is indicated at the right, and so forth. The amount of reactance, of inductive reactance connected across KL can be varied, of course, by changing the size of the half turn loop. If the side wires of such a pair were open and had no cross connection like MN, they would act like the plates of a condenser and so supply capacitive reactance. When they are closed in this way by the pair LN with the connections, and where the lengths are less than a quarter of the wave length used in the antennas we are considering here, they provide an inductive reactance, and that amount depends on the size of the loop, that is to say, upon the length of the side wires, K to N and I to N.

In antenna No. 2, that includes a half turn loop, 17.7 feet long, after its adjustment, and that was the measure of inductive reactance provided by the loop. I have already pointed out that these adjustments are described in the stipulated description, Exhibit 10, as providing an approximate impedance match at KL and resulting in a reduction of the reflection of waves from KL towards the transmitter.

The variable inductive reactance connected in the sixth [fol. 199] quarter wave section, instead of in the second quarter wave section is one of the cases of a more remote connection described at the portion of the specification beginning at line 60 on page 1.

The value of the inductive reactance provided by the loop is chosen so that in cooperating with the electrical constants of the length of the line section from KL to CD and further in cooperating with the value of the load resistance of the antenna at about the points CD, there is attained the final result of a practical impedance match such as will reduce reflection from the points KL. The practical result of that is the long, high efficiency transmission line of the first Carter patent, but provided by the specific matching arrangement described in the second Carter patent.

Mr. Blackmar: I wish to offer in evidence the sketch of the impedance matching system of antenna No. 2 original referred to by the witness in the course of his last answer.

(Marked Plaintiff's Exhibit 30 in evidence.)

Q. 88. Mr. Hogan, in connection with this impedance matching system of this particular antenna, is there anything besides the load, which, as I understand it, is represented by the antenna, and appears at point CD; and the portion of the transmission line between the load and the parallel connected reactance, that portion being the wires CK and DL: and the reactance itself, which I understand is the U loop KMNL, which enter into the matching circuit?

A. No, there is nothing else; those three things, the load, the line section and the reactance connected across the line [fol. 200] comprise the matching system.

Q. 89. In the system of this antenna are there any serially connected impedances in the transmission line between the source and the load?

A. No, there are none.

Q. 90. Now will you please describe other details of that antenna system No. 2 in its original form.

A. The WML original antenna No. 2 is a directional short wave antenna and it is made up of two wires, AC and BD, which are simple linear conductors. Those wires are long relative to the working wave length, the distance AC and the distance BD being 517 feet, or very nearly seven and three-quarter wave lengths. The two wires are in a single plane and together they lie on one side of the connection point CD. The wires of the WML antenna have insulated or open ends at AB, and that favors the development of standing waves by reflection on the antenna wires. In fact, the stipulated description, Exhibit 10, points out that waves are intentionally reflected between the antenna ends AB and the point MN by way of KL. That reflection provides the desired standing waves along the wires AC and BD.

The two wires are coupled to the transmitter through the transmission line so that they are excited in phase opposition, as is also set forth in the stipulated description, and as a result of that, the standing waves have opposite polarities at corresponding points on the two wires at any particular instant.

The principal radiation from the No. 2 antenna is concentrated in the plane of the wires. Further, the radiation from antenna No. 2 is concentrated by the strengthening of one pair of lobes and the weakening of another pair of [fol. 201] lobes of radiation from each of the two wires.

As a result of that, the antenna No. 2 system has bi-directional radiation. As I have pointed out, I think, the destination points lie almost exactly or approximately along the line which bisects the angle of the V antenna No. 2.

Q. 91. Will you please compare the system of this antenna No. 2 in its original form with the disclosure of the second Lindenblad patent in suit, Plaintiff's Exhibit 4, with particular reference to Fig. 2 thereof?

A. Original antenna No. 2 also embodied the features of the Lindenblad patent 1,927,522, Fig. 2. As in the patent, the long open-ended wires were excited in phase opposition, as I have already explained, and as in the Lindenblad patent, they gradually diverged as they were extended from the end of the transmission line CD towards the open ends AB. Thus they were like the arrangement of Fig. 2 of the Lindenblad patent.

The length of seven and three-quarter wave lengths, very nearly, is within the range of from five to ten wave lengths, which is suggested by Lindenblad at page 2, lines 120 and 121.

The axis of the WML antenna system lay in the general direction of principal radiation, the destination points being almost exactly or approximately on that axis, and the desired radiation therefore taking place in the direction specified by Lindenblad in the middle of the first column of page 1.

Q. 92. Will you please compare the system of this antenna No. 2 in its original form with the disclosure of the third Carter patent in suit, Plaintiff's Exhibit 5?

A. The original antenna No. 2 used with call letters WML [fol. 202] corresponds generally to the simple V shown in Fig. 2C of the third Carter patent. The WML antenna, like the Carter antenna, was composed of long linear conductors carrying standing waves, and it was disposed substantially at the angle taught by Carter, so that the radiation occurred principally along the direction of the bisector of the angle, as illustrated generally in Fig. 3 of the Carter patent.

Antenna No. 2 corresponded generally to the arrangement of Fig. 4 of the Carter patent, except that it did not include the second vertical concentration wires A′ and B′. The included angle of original antenna No. 2 was 35 degrees, as is shown in the diagram of Exhibit 10, and therefore

the angle between each wire and the bisector was 17½ degrees.

From Fig. 12, the chart of the Carter patent, based upon the formula that he gives at line 85 of page 2, the preferred angle for maximum radiation for wires 7.74 wave lengths long would be 17.8 degrees. If the angle of No. 2 antenna had been 17.8 degrees instead of 17.5 degrees, as it was stated to be in the stipulated description, the power multiplication of the signal in the desired direction as compared to the signal which would be received from a half wave dipole antenna with the same power, would have been 9.9 times, whereas with the 17.5 degree angle, the power gain was 9.8 times. Therefore the power gain percentage for the angle actually used in antenna No. 2 original, was approximately 99 per cent. of that which would be had if the exact preferred angle had been used.

This antenna No. 2 was tuned and adjusted by means of [fol. 203] the U-shaped loop, extending from MN to the antenna point CD, that loop being of the sort shown in Figs. 2-C, 5 and 11, of the third Carter patent. It is formed of the cross connection MN and the parallel wires KIC and LJD extending from MN.

Thus the antenna utilizes the arrangement that is explained at page 2, lines 114 and following of the third Carter patent.

I have already pointed out in connection with the Lindenblad patents that the two wires of the V are excited in phase opposition through the transmission line, which is also true of the antenna of the third Carter patent; and also that the wires have open ends so that standing waves are developed along their lengths; and that the standing waves have opposite polarity at corresponding points along the two wires at any particular instant.

In all of these things, the antenna No. 2 corresponds to the disclosure of the third Carter patent.

Q. 93. Now, Mr. Hogan, referring to this description and the model, if they will help you in any way, will you please describe generally the system of antenna No. 8?

A. On the map, which I think was Exhibit 23A, the No. 8 antenna is shown by the double V at the southwest corner of the property. It is illustrated as to its construction diagrammatically in the drawing attached to Exhibit 7 and it is described in considerable detail in the text of the tabu-

lation, the text of Exhibit 7 and the tabulation of Exhibit 13. It is also represented by the scale model, Exhibit 29. The antenna system comprises two V's both located in the [fol. 204] same horizontal plane 80 feet above the ground approximately and with their corresponding side wires parallel to each other.

The included angle of each of the two sections is, as shown on the diagram, 45 degrees. Both sections are supplied with radio frequency power at the operating frequency of 5990 kilocycles through a two-wire transmission line that extends from the transmitter a distance of about 800 feet to the points IJ which represent the junction point beneath the apex of the nearer antenna section. From that point the transmission line extends horizontally 123 feet further to a point below the apex of the second V and also extends upwards a distance of 42 feet from each of the points below the respective apices to the corresponding apex of each section.

The call letters used with the antenna were WMZ or WMZ-20 and the wave length is 50.08 meters, or 164.3 feet. The antenna was stated to be used for transmission to San Francisco and to Chicago. The great circle bearings of those two cities from Sayville are respectively north 281.28 degrees east and north 278.46 degrees east. The direction of the bisector of the two V's which is called the directivity of the antenna in the stipulated tabulation of Exhibit 13, when that is taken from the center of the V's toward their open ends, is north 281.95 degrees east. Consequently, the bisector bears almost exactly upon San Francisco and closely on Chicago.

Q. 94. Will you please compare the structure of antenna No. 8, Defendant's antenna No. 8, with the disclosure of the first Carter patent, particularly with reference to the first [fol. 205] objects stated therein at page 1, lines 24 to 31?

A. In this antenna No. 8 the transmission lines which deliver power from the power house or transmitting generator to the antennas or to the two antenna sections are 842 feet long to the points CD on the one section and 965 feet long to the points C'D' on the second section. The 800-foot portion from the transmitter to the points IJ is common to the transmission line to each of the two antenna sections.

The lines have uniform characteristics throughout their lengths, being made of the same No. 6 wire with 12-inch spacing to which I referred in connection with antenna No. 2. Thus they have a characteristic or surge impedance of approximately 600 ohms.

In this antenna system there are three points where there are electrical conditions of the sort that would set up substantial reflection of energy back toward the transmitter and therefore would produce standing waves in the line connecting to the transmitter unless impedance matching arrangements were provided.

The first of those points which would tend to set up reflection is the junction point IJ, where one transmission line divides into two sections of a transmission line. The other two points are at or near the antenna apices CD and C′D′, where the change from the antenna into the transmission line has its effect.

Referring to this first Carter patent, I may point out that the arrangement of the No. 8 antenna corresponds generally to the showing of Fig. 3 in the patent. Thus the two Sayville antenna sections AC, BD, and A′C′B′D′ correspond to antennas 31 and 34 in the patent drawing. The [fol. 206] transmission line 10′ from 37′ to 38′ corresponds to the antenna No. 8 line from IJ to C′D′ by way of I′J′ supplying power to the right hand antenna in both pictures.

The shorter transmission line marked 10 in the patent drawing running from 37 to 38 corresponds to the shorter transmission line from IJ to CD, supplying power to the left hand antenna, section of the antenna system No. 8, and also the left hand antenna 31 in the patent drawing.

At Sayville there is a single source or transmitter indicated at the left of the chart of antenna No. 8, and power from it is supplied to both antenna lines and to both antenna sections over the long common transmission line from the transmitter to the power junction IJ.

In Fig. 3 the power junction is at this three-coil transformer having the coils 13, 37′ and 37, and power from the transmitter in the patent drawing is supplied over the wires connecting to the coil 13.

With respect to the patent, in a case corresponding to the case of Sayville's antenna No. 8, if the power junction IJ, or, looking at the patent drawing, 13, 37 and 37′, is at a considerable distance from the transmitter, it follows

from Carter's teachings that the long transmission line must feed into a matched load in order to obtain the desired high efficiency line substantially of electrically infinite length or substantially reflectionless.

At Sayville, there is a match between the surge impedance of the line, and the load which is presented at or close to the junction point IJ, and that match is provided by means of the line section, which extends from IJ to the [fol. 207] connections KL, and by the line shunt reactance provided by the wires KM and LN. In their effect, the line section and the reactance connected across the line are equivalent to the impedance matching transformer 13, 37, 37′ shown in Fig. 3 of the Carter patent, when that transformer is adjusted to match to the load of a long line from the generator to the coil 13.

The stipulated description states that in antenna No. 8 an approximate impedance match was provided at KL, and by reason of that energy was efficiently transformed across the points KL and reflection of waves towards the transmitter from those points was reduced. Thus there has been made at the time the antenna was installed and adjusted in antenna No. 8 the adjustment that is described by Carter in which the reflection on the long line back towards the transmitter from the junction point or the corresponding matching points is reduced or minimized so as to make that line substantially of electrically infinite length as we are using that phrase, or substantially reflectionless, and so to provide the desired high efficiency of the line.

I might point those elements out on the model, if your Honor would care to have me do so. The long line extends from the transmitter house to the first pole, and across that is connected at a point some distance back toward the transmitter, relatively a few feet, a pair of parallel wires which constitute a shunt reactance connected across the transmission line at the point before the junction is reached. Then the transmission line carries forward to the junction and goes in two directions, first, horizontally to the second [fol. 208] antenna section, and vertically to the first antenna section.

There are two other matching circuits, one at each of the antenna systems, to which I will refer later; the one which has to do with the prevention of reflection along the main line is the one below the junction point which I have already described.

Q. 95. Now, will you please compare defendant's antenna No. 8 with the disclosure of the first Carter patent, particularly with respect to the second object stated therein, at lines 31 to 36 of page 1?

A. Yes. In this connection we are interested particularly in the portion of Fig. 3 described in connection with matching the transformers 38, 32 and 38′, 35 of Fig. 3 of the patent. At page 2, beginning at line 10, it is pointed out that they are to be adjusted, so as to make the lines 10 and 10′ of electrically infinite length, that is to say the same adjustment is to be made at those coils as had been described in the earlier part of the patent, as to the coils in Figs. 1 and 2. That results in making the antenna load resistance in each case match the surge impedance on the associated transmission line.

Now, in the Sayville antenna No. 8, that same match is provided for each of the two antennas and the directly connected transmission lines associated with each of the antennas are matched in that same way by means of equivalent matching circuits EGHF for antenna ACBD and E′G′H′F′ for the antennas section A′C′B′D′.

It is set forth in the stipulated description in the same way that an approximate impedance match was provided at [fol. 209] each of the pairs of the points E′F′ and EF, and also the description sets forth the result that energy is efficiently transferred across each of those pairs of points and reflection of waves towards the transmitter from each of those pairs of points is reduced.

The object of the impedance matching directly below each antenna section in antenna No. 8, or in any other multiple radiator directive antenna system of the same type, is in accordance with that of the second object of Carter's specification, the second object of Carter's invention, which is stated at page 1, lines 31 and following of the specification.

I have explained in connection with the patent when you use transmission lines of electrically infinite length, even though the physical length may be relatively short, it is possible to fix and maintain the proper relations of the phase and intensity of the currents in the several antenna sections in the way Carter pointed out on page 2 of the specification, beginning at line 40.

In Fig. 3 and Fig. 4 of Carter's first patent, the spacing between the antennas is only a quarter of a wave length,

and at Sayville the spacing between the two antenna sections is only 123 feet, or three-quarters of a wave length.

When you have such short transmission line sections as those between the two antennas in Fig. 4, for example, or the three-quarter wave length section between the two antennas, in the antenna No. 8, the increase of transmission line efficiency in that part of the line that results from the matching is not of great importance. It is much less important, for example, than the provision of the simple and effective way of fixing the relative phase and excitation of [fol. 210] the two antenna sections in accordance with Carter's second object.

Of course, insofar as the current in those lines is reduced and therefore radiation from them is minimized, and thus prevented from having any effect, or having as great an effect upon the radiation pattern of the antenna, it is useful from the mere point of efficiency, but the most important thing is the control of the phase and amplitude relations.

I might point out those two loops briefly in connection with the model. Here, instead of having a pair of open wires connected across the transmission line, there is a closed loop directly below the apex of the antenna. Similarly on the other antenna section a closed loop is connected directly across the transmission line directly below the apex. That provides the match where the loop is connected across in connection with the vertical section, and therefore prevents standing waves on the transmission line section between the two antennas, which allows one to fix the phase and amplitude relations in a system in a way that could not be done otherwise.

I might summarize with respect to this first Carter patent and antenna No. 8 by pointing out that both, as shown in Fig. 3 and antenna No. 8, have their antenna sections spaced by an odd number of quarter wave lengths, that they are supplied with equal radio frequency power in such relative phase as to be unidirectional; that in each case, the single transmitting generator is connected to the two antennas by means of a two-wire transmission line, substantially of an electrically infinite length; and with respect to the first [fol. 211] object that the impedance match at the power junction provides a high efficiency long line and makes possible the use of antennas erected at a considerable distance from the transmitter house; and with respect to the second object, that the impedance match in the antenna connection

itself permits use of the transmission line length to determine the phase difference and to maintain that as between the two antenna sections, and also to determine and maintain the relative current values. In that way, the No. 8 antenna also embodies the specific features that I have described in connection with the first Carter patent and attains the objects that he sets forth.

Q. 96. Have you prepared a diagram of the impedance matching system of this antenna No. 8?

A. Yes.

Q. 97. Will you explain, please, how the impedances are matched in this antenna system at the junction point IJ, or rather at KL, and compare that matching circuit with the second Carter patent in suit?

Mr. Blackmar: At this point, I offer in evidence the diagram of the impedance matching system of antenna No. 8 referred to by the witness.

(Marked Plaintiff's Exhibit 31 in evidence.)

A. This Exhibit 31 is generally an expanded layout of the impedance matching system, for antenna No. 8, following the same general conventions as those which I used for antenna No. 2, in order to show the matching arrangement [fol. 212] in greater detail than could be done in the drawing attached to Exhibit No. 7, the stipulated description.

There are three impedance matches in this system of antenna No. 8, and all of them are attained by means of the specific type of matching circuit that is described in the second Carter patent 1,909,610. The first match is the one as to which this question was directed, and is the one shown at the lower part of Exhibit 31, where the line from the points IJ to the transmitter is shown extending off to the left. The distance of 12 feet between IJ and KL is subtracted from the total distance of 800 feet to the transformer, giving a balance of 788 feet from the points KL to the transformer.

The transmission line has a surge impedance of 600 ohms, and the load at IJ is made up of two similar transmission lines, connected in parallel to that same point. Therefore the resistance of the two lines together, the joint effect is of the general order of one-half that of one line, and therefore of approximately 300 ohms.

That, of course, gives at IJ a load resistance which is less than the surge impedance of the line back toward the transmitter.

There is a shunt reactance marked "Capacitive Reactance" in Exhibit 31, provided by the two 15-foot wires KM and LN, and that reactance is connected to be effective at the point KL, as I have said, 12 feet back towards the transformer from IJ.

Now, the first quarter wave section from IJ back toward the transmitter extends 41 feet. Consequently the connections KL are within that first quarter wave section shown in [fol. 213] Exhibit 31, and being a capacity or capacitive reactance across the line and connected in the first quarter wave section, are of the character to use where the load resistance is less than the surge resistance of the line, and therefore correspond to case No. 1 of the tabulation on page 2 of the Carter patent as is described at page 1, lines 28 and following, and page 2, lines 18 and following, and as is illustrated by Fig. 2 of the patent.

Q. 98. Referring to the chart, will you explain what the figures are above the words, "Impedance Matched at KL", and what they indicate?

A. The figures immediately above "Impedance Matched at KL", on the chart are the Greek letter lambda stroke 4, and that is a shorthand way of saying one-quarter wave length. In other words, the wave length divided by 4. The distance represented by the arrows on each side of this symbol indicates the extent of the quarter wave length section, although, of course, this diagram is not drawn to scale, but it is relatively correct.

Referring to this Fig. 2 of the patent, the source of alternating current energy 2 in the drawing corresponds to the transmitter of antenna No. 8. And the line marked 6, in the patent drawing, corresponds to the main line or 800 foot transmission line with its surge impedance of about 600 ohms.

The capacitive reactance 10 which is required for case 1 of the Carter patent is provided in antenna No. 8 by the capacity between those two open ended wires KM and LN to which I have referred. Each of those wires acts as one of the plates of a condenser, the effective value of the capacity [fol. 214] reactance being determined by the size, that is to say, by the length of those wires in this case. The load

marked 4 in Fig. 2 of the patent is represented by the resistance at IJ, the junction point, and that being of the order of 300 ohms, it is less than the surge impedance of 600 ohms, and that corresponds with the statement at page 1, lines 81 to 85 of the patent.

In Fig. 2 of the patent, the distance between the load and the cross connected reactance is stated as not over one-quarter wave length. Reference to Exhibit 31 shows that with the load at IJ and the reactance effectively connected at the points KL the distance between them is not over a quarter wave length.

Therefore we have a situation in which the value of the load, the length of the line section between IJ and KL and the value of the capacitive reactance effective at KL combine to produce an impedance match at the points KL, just as explained in the Carter patent. This depends upon the length and position of the wires, bearing in mind that the length KM-LN determines the amount of the shunt capacity reactance and the length of the line section is determined by the point of connection. Those two things were adjusted when the antenna system was installed to provide efficient transfer of energy across the points KL and thus to reduce the reflection of waves toward the transmitter, as is stated in the stipulated description of antenna No. 8.

That describes the condition of a practical match between the surge impedance of the line and the resistance of the load which results in the desired high efficiency long line.

[fol. 215] I pointed out that the length of the line from the matching points KL to the transmitter was about 788 feet, but I did not point out that that was equal to about four and three-quarter wave lengths.

Q. 99. Will you please compare the other two matching circuits, namely, those at the antennas, in connection with this antenna system No. 8, with this second Carter patent?

A. Yes, the two matches on the transmission lines just below the antennas are indicated by the central and upper figures in Exhibit No. 31. In each of those there is a pair of points marked IJ, which is to be understood as being connected to the points IJ, on the bottom part of the diagram, and so providing the connection through from the transmitter source to each of the two antenna sections.

Taking up the second impedance match in antenna No. 8 as between the vertical transmission line section running

upward from IJ and the load provided by the antenna ACBD at or near the points CD, I would refer to the upper diagram in Exhibit 31. This match is quite similar to that which I have already explained in connection with antenna No. 2. The situation is very much the same except that in antenna No. 8 the resistive load of the antenna is greater than the surge impedance of the line because points C and D are almost exactly an even number of quarter wave lengths from the open antenna ends A and B and that, as I pointed out, results in a high terminal impedance rather than a low value.

The shunting inductive reactance provided by the half turn loop EGFH is connected 27 feet from CD, that is to [fol. 216] say, in the first quarter wave section, since a quarter wave is about 41 feet, and thus the arrangement corresponds to that of case 2 of the Carter second patent.

The third impedance match in antenna No. 8 is in the vertical below the apex C′D′ and it corresponds to that which I have described in connection with the outer V antenna section. The only difference between the two is a slight variation in the individual dimensions such as would be expected under practical conditions.

The stipulated description sets forth that EGHF and E′G′H′F′ were adjusted to provide an approximate impedance match at EF and E′F′ so as to permit efficient transfer of energy across those points and to reduce the reflection of waves toward the transmitter.

That is the condition that results in obtaining Carter's objects including the stable control, by the length of the transmission line, of the relative phase and current amplitudes in the two antennas, and is an important consideration in connection with obtaining the best directive radiation from a double antenna system of this kind.

Q. 100. In connection with the three impedance matching circuits of this antenna system No. 8, is there in any case anything besides the load, that portion of the line between the load and the shunt reactance and the shunt reactance, that enters into the impedance matching circuit?

A. No, there is none. The match is attained by the cooperation between the load, the section of transmission line between the load and the matching point, and the shunt or effective reactance connected across the matching points.

Q. 101. And only by those elements?
A. That is correct.

[fol. 217] Q. 102. In either case is there any serially connected impedance in the line between the source and the load?

A. No, the line is uninterrupted from the source to the load.

Q. 103. Will you please describe other details of the system of defendant's antenna No. 8?

A. Looking at either section of antenna No. 8, which is a double V antenna, it is clear that it is substantially identical with the single V antenna No. 2 that I have already discussed, except, of course, as to the matter of dimensions. The No. 8 antenna also has features that I have described in connection with the No. 2 antenna. It also has some of the additional features not present when only one pair of wires is used.

Summarizing briefly, the radiating wires are each four wave lengths long, the antenna is directive, the wires of each of two pairs are supplied with power in phase opposition, and all the antenna wires carry standing waves. The standing waves of each pair of wires are of opposite instantaneous polarity. All of the wires have open ends. That provides reflection points and favors the development of standing waves in the radiating parts of the system. And the principal radiation is along the line that bisects the included angles of the two V's.

Like antenna No. 2, also, the radiation is concentrated generally in the plane of the wires, and the wires of each of the two sections of the antenna are arranged so as to diminish one pair of lobes and thus to augment the other pair. That provides, for each unit, bi-directive radiation.

Antenna No. 8, however, brings in another feature of the [fol. 218] first Lindenblad patent, namely, that which is described in the specification beginning at line 43 of page 3. That is the provision of a second pair of wires similar to the first pair, and each one having its corresponding wire parallel to that of the other pair.

Those two pairs are arranged at a distance of an odd number of quarter wave lengths in the direction of wave radiation, and they are excited with the relative phase difference that will cancel one-half of the bi-directive radiation from

the single pair. That not merely cancels one of the lobes, but reinforces the other one and so gives increased unidirective radiation. In the case of antenna No. 8, that unidirective radiation is projected almost exactly in the plane containing a great circle bearing toward San Francisco.

Q. 104. Will you please briefly compare the system of defendant's antenna No. 8 with the disclosure of the second Lindenblad patent in suit?

A. Referring again to Fig. 2 of the second Lindenblad patent, 1,927,522, I would only point out that this No. 8 antenna, like the No. 2 original form of antenna which I have already described, embodies the features disclosed in the second Lindenblad patent with relation to Fig. 2. One may consider either the section ACBD or the other section with the prime letters. There are two long open-ended wires which are excited in phase opposition. The two wires of each pair diverge as they are extended from the apex, from CD or C'D' in the general direction of principal radiation. The axis of the antenna system lies in that direction of principal radiation and the destination points, stated as San Francisco and Chicago, lie quite closely along that axis.

[fol. 219] Q. 105. Will you please compare defendant's antenna No. 8 with the disclosure of the third Carter patent in suit, Plaintiff's Exhibit 5?

A. The explanation that I gave in connection with antenna No. 2 applies generally with respect to antenna No. 8, since antenna No. 8 is made up of two single V sections. Of course, the preferred angle for No. 8 is different because the wave length used is different and the length of the side wires of each of the V's is different from that in antenna No. 2. However, for antenna No. 8, where we have side wires that are an even number of half waves long, the preferred angle may be determined either from the formula at page 2, line 70 of the specification, or from the general formula covering all lengths at page 2, line 85. The wave length used with antenna No. 8 is 164.3 feet, and each side wire is 657 feet long. Thus, the length of each wire is almost exactly four wave lengths and either from the formulas or from the chart, Fig. 12 of the patent, the preferred angle between either wire and the bisector would be 25 degrees.

In the actual case of antenna No. 8, the angle from the wire to the bisector is half of the included angle of 45 degrees, or 22.5 degrees. That, of course, is 2.5 degrees

smaller than the preferred angle. For practical purposes, however, the angles are effectively the same. The angle used, that is to say, 22.5 degrees, causes the radiation from the system in the desired direction along the bisector to be 12.1 times as powerful as the radiation from a simple di-pole antenna would be with the same power.

If the preferred angle of 25 degrees had been used, the [fol. 220] power gain would only have been increased by a small amount, namely, to 12.6 instead of 12.1, and, consequently, with the angle used, antenna No. 8 has more than 96 per cent of the power gain that would be had if they were in perfect agreement with the preferred angle.

The two sections of antenna No. 8 are so arranged that their combined radiation is principally unidirective and in the direction of the bisector; as I have explained, and as the specification sets forth, particularly at page 1, lines 43 to 55, and then again in connection with Fig. 5 of the patent, at page 3, lines 60 to 88, antenna No. 8 corresponds quite closely to the showing of Fig. 5 of the patent, the principal difference being that in antenna No. 8 the lower wires which are not marked with reference characters in Fig. 5 are omitted. Those are the additional wires for causing additional concentration of the radiation with respect to the vertical plane, and I think I have pointed out that those were not used by defendant.

In Fig. 5 of the patent, as also in antenna No. 8, there is a supply of high frequency power from the transmitter by means of a transmission line. The line is marked 24, or the connections to it, in Fig. 5. There is in Fig. 5 a rectangle just to the left of the left hand pole, which indicates a device for matching impedance at the junction joint, and in the case of antenna No. 8 the match for that point is provided by the circuit including the IJ, KL and MN, which I have already described.

The impedance matching device of Fig. 5 is described at page 3, lines 148 and 150, with the reference numeral 40 in its similar application to Fig. 11, but is not marked with a reference numeral in Fig. 5 of the patent.

[fol. 221] In the arrangement of Fig. 5 a branch of the transmission line extends upward to the apex of the left hand V and another branch of line is provided to connect it to the apex of the right hand V. That same situation exists in the case of defendant's antenna No. 8.

In Fig. 5 both the antenna sections are tuned and matched to the lines by means of parallel wires and U loops from the apices to the short circuiting members 32 and 32′ in Fig. 5, and those correspond with the loops CD, EF, GH, and the same reference letters with primes, in the two sections of antenna No. 8.

Similarly, in Fig. 5 of the patent the V wires themselves are electrically open-ended, and in the defendant's antenna No. 8 the antenna wires are electrically open-ended or insulated. Insulators are shown, for example, at reference numerals 22 of the patent drawing, and by the open ends AB, A′B′ in the chart of Exhibit 7, showing defendant's antenna.

The unidirective radiation pattern of the antenna of Fig. 5, showing the power distribution in the horizontal plane, is given at Fig. 6 of the patent and described by reference at page 3, line 73 of the specification. That patent is also illustrative of the unidirectional radiation from an antenna of the kind represented by defendant's No. 8. The cancellation of backward radiation and the reinforcement of the desired forward radiation is produced both in the arrangement of Fig. 5 and in defendant's arrangement by spacing the two antenna sections by an odd number of quarter wave lengths measured along the bisector. That is referred to specifically at page 1, line 45 of the patent, and again at page 3, lines [fol. 222] 60 to 67. The patent states there that the distance may be, in the preferred arrangement, equal to an odd number of quarter wave lengths.

At page 4, lines 16 to 19, Carter points out that for wires of the order of three or four wave lengths long the reflector spacing from the antenna may be one and one-quarter wave lengths or less. In this case the wire length is four wave lengths and the spacing is the next odd multiple less than one and one-quarter wave lengths, that is to say, three-quarters of a wave length.

In the example of Fig. 5 of the patent that distance is given as nine quarter wave lengths, Carter having pointed out the desirability of increasing the number of quarter wave lengths so long as an odd number is used, as the length of the wire increases.

In addition to that matter of spacing, it is necessary to excite the two pairs of wires so that the currents in one pair have a phase difference of 90 degrees with respect to the currents in the other pair. And both in the case of the antenna of Fig. 5 of the patent and antenna No. 8 of the

defendant, that is done by means of matched horizontal transmission line section extending from one section to the other, that is, the length from IJ to I'J' in antenna No. 8, which is, as I have stated, an odd number of quarter wave lengths long.

Relative phasing of that kind with equal antenna currents in the two sections results in a practically complete cancellation of backward radiation and it is the preferred case for two antenna sections of the condition that is established by the little phase difference formula at page 3, line 125, as to which I was questioned this morning.

[fol. 223] The application of that formula is quite simple, in that it works out that if the spacing, S, is one-quarter wave length, the timing should be pi over 2, or 90 degrees, pi being equivalent to 180 degrees.

Q. 106. If the spacing is three quarters wave length, as it is in the case of defendant's antenna 8, what is the result of that formula?

A. The resultant comes out three pi over 2, or 270 degrees, which is the same as minus 90 degrees, that is, 90 degrees in the other direction. Therefore, the phase difference is still 90 degrees, since it takes no account of sign.

I have already pointed out as to this antenna No. 8 in connection with the Lindenblad patents that the two wires of each V are excited in phase opposition through the transmission lines. The V's have got open or insulated ends and in that way the development of standing waves along their lengths is favored. Because of the excitation in phase opposition, those standing waves have opposite polarity at corresponding points along the wires at any instant.

Because of the phase difference produced by the horizontal section of the transmission line extending from the point below one apex to the point below the other, the standing waves at corresponding points on the two corresponding and parallel side wires of the two V's that is, for example, AB and A'B', are 90 degrees out of phase at any particular instant.

That summarizes the similarity in the features of the antenna described in the patent and of No. 8 of the defendant represented by the model and shown in the drawing attached to Exhibit No. 7.

Q. 107. Going back to the first Carter patent in suit, Plaintiff's Exhibit 3, will you very briefly compare its dis-

[fol. 224] closure with the other single V antennas at Sayville where there is any difference between them and No. 2 already covered?

A. In connection with this first Carter patent, I have described single V antenna No. 2 in its original form. The other single V antennas at Sayville are No. 2, as it was rebuilt, No. 3 in its original form, that is, as it was when the suit was filed, No. 3 as it was rebulit, and No. 11.

Now, Nos. 2 and 3 in both their original and their rebuilt forms are illustrated by the drawing of the WML antenna system which was part of Exhibit No. 10, that being modified, of course, by the dimensional differences and any other data given as to [illegible] in the tabulation of Exhibit 13, the column arrangement to which I referred this morning.

The only structural difference between those three antennas is that the matching circuit reactance KMNL in the rebuilt antenna No. 2 was open instead of having a cross connection; changing, therefore, from an inductance to a capacity reactance.

Antenna No. 11 is a little different, however.

Q. 108. Have you prepared a chart of the impedance matching system of antenna system No. 11?

A. Yes, and in connection with that I would like to refer to the drawing of antenna No. 11 which is annexed to Plaintiff's Exhibit 11.

Mr. Blackmar: I will offer in evidence the chart of the impedance matching system of antenna system No. 11 to which the witness has just referred.

(Marked Plaintiff's Exhibit 32 in evidence.)

[fol. 225] A. (Continuing.) In this antenna No. 11, illustrated in Exhibit No. 11, the resistance of the antenna is matched to the surge impedance of the transmission line by means of a matching transformer that is made up of two adjustably spaced parallel copper tubes marked EG and FH instead of by the matching circuit shown in Exhibit D.

These tubes, your Honor, are located vertically just below the apices of the antenna and form part of the transmission line connection from the transmitter to the antenna.

It has been shown quite recently, comparatively recently, that copper tubes of that sort, if they are one-quarter of a wave length long and if they are properly adjusted as to

their spacing and diameter and their location, may be used as an impedance transformer for impedance matching.

So far as securing the desired matching of the line and the load impedance is concerned, their use is equivalent to the transformer type of circuit shown in the first Carter patent. Those two copper tubes, the vertical copper tubes, and their connections, provide a combined transmission line and impedance matching transformer.

The detail diagram of Exhibit 32 shows this system of antenna No. 11 leading out along a straight line across the paper.

It also shows that the load resistance corresponding to an odd number of quarter wave lengths for the wire and being less than that of the surge impedance of the line, the tube spacing and adjustment of length works out to give a substantial match. That is covered by the descriptions attached to the stipulation stating that in all of the antennas an approximate impedance match was provided by the ad-
[fol. 226] justments made when each antenna system was installed.

The same statement is made as to all the antennas further that that resulted in an efficient transfer of energy across the matching points which here are the points GH at the lower ends of the tubes; and resulted also in reduction of reflection of waves toward the transmitter.

The explanation I have given for antenna No. 2 in its original form therefore applies insofar as the first Carter patent is concerned, to each of the other antennas, No. 2 rebuilt, No. 3 original, No. 3 rebuilt, and No. 11. In each case there either was, if they have been replaced, or is, if they are still in use, a practical match between the antenna resistance and surge impedance of the transmission line, so that each transmission line was made substantially of electrically infinite length, or substantially reflectionless, or having the desired high transmission line efficiency so that the power losses on the long lines would be reduced.

Now, the lines in these several antennas vary very considerably in their length, all the way from the shortest case, which was only a little over 100 feet, corresponding to nearly two wave lengths, right up to the longest case, where the transmission line was over 1100 feet long, or more than 12 wave lengths in length. No. 11 was the short one and No. 3 rebuilt was the longest one.

Q. 110. Now, will you briefly refer to the other double V antennas, and compare them insofar as they may differ from antenna No. 8 with the first Carter patent in suit?

A. The other double V antennas are Nos. 4, 5, 6 and 10, which are illustrated, except as to their dimensions, by Ex- [fol. 227] hibit 8, showing antenna No. 10; also antennas Nos. 1 and 9, which are illustrated, except as to dimensions, by the sketch showing antenna No. 1 in Exhibit 9. And finally No. 7, which is illustrated in Exhibit 12.

Then beyond what is shown in these diagrams there are additional data and specific dimensions given in Plaintiff's Exhibit 13, the tabulation.

Now, referring to Nos. 4, 5, 6 and 10, altogether, and really taking with them antennas Nos. 1 and 9, those are shown by the sketches of Plaintiff's Exhibits 8 and 9. They are all alike with regard to the disclosure of the first Carter patent. They are illustrated in two groups, because those of Exhibit 8 are connected and adjusted so that they radiate principally along the direction of the bisector from the center of the system, toward the open ends of the wires, whereas those in Exhibit 9 are connected so that they will radiate principally from the center of the antenna toward the apices, that is to say, the 180 degree reversal of which we have spoken is used.

That difference in connection and adjustment is described by Carter in his third patent, at page 3, lines 101 and following, but that does not have to be considered in connection with the first Carter patent.

All six of these double V antennas are like antenna No. 8, except as to their frequencies, dimensions and so on, and as to the type of impedance matching device which is used between the junction points and the apices. The matching circuit used between the junction point and the transmitter, that is to say, with respect to the long main feeding line, is [fol. 228] the same in all of these cases, and in antenna No. 8, and therefore need not be described with respect to each antenna.

Similarly the match below the antenna apices in each of these double V antennas is similar to that used with the single V antenna No. 11. The stipulated descriptions cover with respect to these double V antennas, as they did with respect to the single V antennas, that an approximate impedance match is provided between the load at the junction point, which is what we are considering in connection

with the main line, and the surge impedance of the transmission line; and, as I have said before, such a practical match results in making the long transmission line from the transmitter substantially of electrically infinite length, or substantially reflectionless, and thus avoids the power losses and provides the high transmission line efficiency.

Now, the transmission lines from the junction point to each of the antennas, for instance, C′D′ or CD in each of these additional double V antennas are made reflectionless or are of electrically infinite length, by that copper tube arrangement represented by the sections marked EGFH, and E′G′F′H′. I have pointed out that those tubes and their connections are equivalent insofar as producing the desired matching of line surge impedance and load resistance is concerned, and also in supplying power from the transmitter to the antenna loads, to the other type of matching, or to the type of matching that is shown in the first Carter patent.

In all six of these antennas, as in No. 8, the matching devices between the junction points marked IJ and the apices [fol. 229] of each of the antenna sections are effective to transform the resultant load resistance of each radiating section to the value of about 600 ohms that is necessary to match the transmission lines. By providing an effective load of that value for each of the branches of the transmission line, between the power junction IJ and the radiating sections, the currents in the two sections of each of the antenna systems are equalized, and, of course, as I have pointed out, the phase difference is fixed at the desired value of odd quarter wave lengths by the lower horizontal sections; or, in other words, the difference in length of the two transmission lines, connected respectively to each of the two apices, and in that way the second object of the Carter first patent is accomplished.

The only other antenna of the double V type is No. 7. That is like any of the other antennas, 4, 5, 6, or 10, except as to its dimensions, and also except that it omits a matching device in the line from the transmitter to the junction points.

In this antenna No. 7, the length of that part of the transmission line, namely, from the transmitter to the power junction, is only 151 feet, that is only 1.66 wave lengths, one and two-third wave lengths, and as Carter showed, the matching of so short a part of the line is not of great im-

portance. However, in that antenna, the copper tube impedance matching transformers are used in the connections from the apices down to the junctio. points, and in that way the currents in the two antenna sections are equalized, and the line between the two antennas is kept clear of standing waves, so that its length will fix the phase difference in the way Carter specifies, and thus attain the second object of Carter's first patent.

[fol. 230] Q. 114. Now, will you please compare the disclosure of the second Carter patent, Plaintiff's Exhibit 2, with the V type antennas at Sayville, other than Nos. 2 original, and No. 8, insofar as they may differ from those?

A. Yes, leaving out original No. 2 and No. 8, with respect to the other Sayville antennas, Nos. 7 and No. 11, do not have the type of matching circuit that is shown in the second Carter patent. Original No. 3, I understand, had this circuit, but it had dimensions and arrangements, some of which we do not know now, and consequently, I haven't enough data to compare them with the patent.

Mr. Blackmar: I may say in the tabulation of defendant's antennas, giving the dimensional data, there were certain of them which are as entered unknown, and I assume that is because the defendant itself did not know at the time the stipulation was drawn up what they had been.

A. (Continuing.) In the rebuilt form of antenna No. 3, the load resistance is greater than the characteristic impedance of the line, and a shunt inductive reactance is connected across an odd numbered quarter wave length section, which is equivalent to making the line section, length of line, between one and one and a quarter wave lengths, and corresponds to case 2 of Carter's tabulation.

In all of the other Sayville antennas than those I have now referred to, that is to say, in No. 1, No. 2 rebuilt, No. 4, No. 5, No. 6, No. 9, and No. 10, the load resistance concerned in this particular match is less than the character-[fol. 231] istic impedance of the line, and a shunt capacitive reactance is used and is either connected at less than one-quarter wave length from the load point as in antenna No. 10, or on the basis that Carter has pointed out is equivalent to that, across an odd-numbered quarter wave length section, which is what occurs in No. 1, and in No. 2 rebuilt, No. 4, No. 5, No. 6, and No. 9.

All of those arrangements correspond to case 1 of Carter's tabulation. The agreed description in connection with each of those antennas, states that the matching circuits to which I have referred have been so adjusted as to provide approximate impedance matching, permitting efficient transfer of energy across the matching points, and a reduction of reflection of waves toward the transmitter.

Q. 117. Mr. Hogan, in your testimony so far you have compared the antenna No. 2 in its original form, and antenna No. 8 of defendant's Sayville Station with the disclosure of the first Lindenblad patent. Will you please briefly compare the other antennas with the disclosure of that patent, insofar as they may differ from those already taken up?

A. The other single V antennas are No. 2 rebuilt, No. 3 original, No. 3 rebuilt, and No. 11. They are very much the same with respect to the use of long, straight wires supplied with energy in phase opposition, and the other elements which I have pointed out in antenna No. 2.

The other double V antennas are Nos. 1, 4, 5, 6, 7, 9, and 10; and those are generally described as to their structure by what I have said with regard to double V antenna No. 8, and also insofar as that applies to the description of the single V antenna, No. 2 original.

[fol. 232] The lengths of side wires in each of the 13 antennas at Sayville, that is to say, the 11 numbers and the two additional forms of numbers 2 and 3, are given in the tabulation, Exhibit 13. The shortest of those wires is in antenna No. 8, where the side wires are each four wave lengths long; and the longest side wire is in antenna No. 2 as rebuilt. In that case the side wires are 8.14 wave lengths long.

Q. 118. With respect to the disclosure of the second Lindenblad patent, do you find anything in the defendant's antennas, other than Nos. 2 and 8, which differs from them?

A. No, I think that with respect to this patent, what I have said about antenna No. 2 original for the single V type and antenna No. 8 for the double V type applies to all the others, with, of course, the exception that the dimensions are different. The wire lengths of all of the antennas fall within the range of from five to ten wave lengths, which is suggested at page 2, line 121, of the Lin-

denblad specification, with the exception of the rebuilt antenna No. 3, where the wire length is 4.85 waves, and antenna No. 8 which, as I have already said, has side wires four wave lengths in length.

Q. 119. With respect to the third Carter patent in suit, Plaintiff's Exhibit 5, will you please compare the defendant's single V antennas, other than No. 2 original, with the disclosure of that patent, insofar as they may differ from No. 2 original?

A. All of the single V antennas are like No. 2 in that they have open ends; the wires are excited in phase opposition; the wires carry standing waves principally, and those standing waves are of opposite instantaneous polar-
[fol. 233] ity; also in each case, the principal radiation is bi-directive, as typified by Fig. 3 of the patent, and in both directions along the bisector.

Antenna No. 2 as rebuilt has an angle between the wires and the bisector of 20 degrees. For the wave length and the wire length used in that antenna, the preferred angle is 17.33 degrees, according to the Carter rule. That difference of 2.67 degrees is not of practical consequence. It serves to reduce the power gain along the bisector as compared to the signal from equal power applied to a half wave dipole from the multiplier of 10.9 to the multiplier of 9.3, and thus the antenna has about 90 per cent. of the maximum power gain for a structure of its size and general arrangement.

Antenna No. 3 in its original form had an angle to the bisector of 17.86 degrees. The preferred angle for the wave length and wire lengths used in that antenna is practically the same, that is to say, 17.88 degrees, and consequently there was very little if any departure from the maximum power gain of 9.8 times.

Antenna No. 3 as rebuilt has an angle of 21.5 degrees. The preferred angle would be 22.65 degrees, or 1.15 degrees greater. The loss in power multiplication by reason of that departure is only from about 7.1 to about 7, so again the antenna has about 98 per cent of the maximum power gain.

Antenna No. 11 has an angle of 17.5 degrees, and the preferred angle would be 17.88 degrees. That departure of .38 degrees reduces the power gain from 9.8 to about 9.7, and therefore the antenna has about 99 per cent. of

[fol. 234] the maximum power along the bisector again for its size and wave length.

No. 3 antenna as rebuilt is tuned and matched by means of a U loop which comprises the wires from CD, the apex, extending parallel and generally downward by way of the point IJ below the apex and the connection point KL to the cross connection MN.

Q. 120. Will you similarly consider defendant's double V antennas other than No. 8 with respect to the disclosures of the third Carter patent?

A. There are seven double V antennas in addition to No. 8, and they are all like No. 8, in the general items, that is to say, each system comprises two pairs of long open-ended wires; each of the pairs is arranged in the V formation and in all cases both pairs are located in the same horizontal plane with the corresponding wires of the two pairs parallel to each other; also, the two wires in each V are excited through a transmission line in phase opposition and they carry standing waves which are therefore of opposite instantaneous polarity.

Also in each case the length of the horizontal section of the transmission line from the point below one apex to the point below the other apex is an odd number of quarter wave lengths long and in accordance with Carter's disclosure the same number of quarter wave lengths as the spacing of the two antenna sections along the bisector.

That relation results in the condition which gives principal radiation unidirectionally along the bisector either toward the open ends of the V's from the center or towards the apices of the V's.

Antennas Nos. 4, 5, 6, 7, and 10 have their principal radiation toward the open ends, and antennas Nos. 1 and 9 [fol. 235] have their principal radiation toward the apices.

The reversibility of radiation is referred to in the specification at page 3, beginning at line 78, and running on down to line 104, and at the end of that section it is pointed out that by exciting one pair of wires in the opposite 90-degree relation, unidirectional propagation may be obtained in an opposite direction or toward the converging ends or apices of the antenna unit.

And in antennas 1, 5 and 7 the angle between the wires and the bisector is 20 degrees. The preferred angle, according to Carter's rule, is from 19.88 degrees to 19.93 degrees, depending upon the individual wire lengths and wave lengths used, so that it is only about one-tenth of a degree smaller than the actual angle. Thus, the power gain in each case is from 99 per cent. to 100 per cent. of the maximum for the preferred angle, which would amount to 17.2 or thereabouts. That larger gain is due, as I have pointed out, to the additive effect of the two antenna units.

Antennas Nos. 4, 6 and 9 each have an angle to the bisector of 17½ degrees. That is only about one-third of a degree less than the preferred angle for each case. Those preferred angles vary from 17.86 to 17.9. The power gain in each case is about 99 per cent. or more of the maximum attainable for those structures and wave lengths and that maximum is about 19.8 times.

Antenna No. 10 also has an angle of 17½ degrees, and that is about one degree less than the preferred angle for the wire length and the wave length used, namely, 18.53 degrees. That departure causes less than one per cent. reduction in the maximum power gain of 18.8, and there- [fol. 236] fore the agreement again is very good as compared to the radiation of maximum power.

Cross-examination.

By Mr. Darby:

X Q. 121. In answer to Q. 65 [R. p. 171], you were stating there the advantages of the first Lindenblad patent, Mr. Hogan, and you gave as part of your statement of the fifth advantage, namely, "the simple long wire antenna of this character has a high radiation efficiency, and by that I mean that a large percentage of the power applied to the antenna is radiated in the form of waves." And you say further, "In an antenna of this sort the radiation efficiency of the order of 90 per cent. or more is customary, whereas in antennas like the Model A, the curtain type antenna, the complicated network of which we have spoken, an antenna efficiency of 50 per cent or thereabouts, is about all to be expected."

What do you mean by "antenna efficiency", did you mean the same thing as radiation efficiency or what?

A. Yes, I was thinking of the fact that in the Model A, for example, there are losses in the tuning coils and supports which reduces the radiation efficiency, and by that I am distinguishing from the directive efficiency, of course.

X Q. 122. You use the term "radiation efficiency" in the one instance and antenna efficiency in the second instance. I was wondering if you meant the same thing.

A. It probably would have been better in that case if I had said radiation efficiency in both cases. Antenna efficiency is perhaps too general to use there.

X Q. 123. So that you mean to state, as I understand your testimony now, that the radiation efficiency in one instance [fol. 237] is 90 per cent and in the other instance was 50 per cent?

A. Yes, that is rough figures.

X Q. 124. Will you turn to the third Carter patent, and particularly Fig. 11?

A. Yes, sir.

X Q. 125. Will you tell me what is the little box-shaped device in the Fig. 11 of the third Carter patent, that is marked 40?

A. That is an impedance matching device. I think it is described in the specification merely by name.

X Q. 126. I presume, referring to Fig. 5 of the third Carter patent, that the little square device to the left of the figure and connected across the line 24 is likewise intended to represent an impedance matching device?

A. That is my understanding of it. Reference in the specification, as to Fig. 11, occurs at page 3 in the last three lines: "Energy is fed to the system through an impedance matching device 40."

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X Q. 299. Now, I would like to refer you to the two figures 3 and 4 of the first Carter patent, as well as to Fig. 1 of the first Lindenblad patent 1,884,006. Will you tell me generally what is the difference between Fig. 1 of the Lindenblad patent and Fig. 5 of the first Carter patent?

A. Fig. 1, you asked for the difference, not the similarity?

X Q. 300. Well, either. Give me both.

A. All right. They are similar in that they are both plots or graphs indicating the distribution of radiation

around an antenna system. They are different in that Fig. 1 shows the characteristic cross section of a doughnut which represents the radiation around the half wave di-pole rep- [fol. 238] resented by the wire 2 in the center of Lindenblad's Fig. 1, whereas Fig. 5 of the Carter patent represents the horizontal directive characteristic of a pair of antennas with quarter wave spacing, as I have explained in connection with Figs. 3, 4 and 5.

X Q. 301. Does Carter 1 show a half wave di-pole structure?

A. Carter?

X Q. 302. Patent No. 1,263,996, does that illustrate a di-pole antenna system?

A. No, it represents a horizontal pattern that could be had with two vertical di-poles separated a quarter of a wave length, and excited in quarter phase relation, but it is not limited to that, or stated to be that.

X Q. 303. But what is illustrated, is the antenna radiator 2, for example, is that a di-pole, is that similar to a di-pole?

A. No, no, except in the general sense that they are both radiators, and so on.

X Q. 304. Now, I understood you to say that it was known even prior to this Carter patent that if you wanted to eliminate the rear lobe, and make an antenna unidirectional, you would place a second antenna spaced and phased for example in quadrature, and you would obtain that unidirectional effect, is that correct?

A. Very broadly, I think that is correct, yes; that is, that the cancellation in the rearward direction produced by the arrangement of two vertical antennas, for example, the quarter wave separation, and excited in quadrature, as you expressed it, did exist and was known prior to the application for this patent.

X Q. 305. So that that feature was not novel with Carter [fol. 239] in his Figs. 3 and 4 at the time of his application?

A. I think that is correct.

X Q. 307. Fig. 1 of the Carter patent does produce a pattern similar to Fig. 1 of the first Lindenblad patent, in that it is not unidirectional?

A. Well, the pattern of Fig. 1 would be substantially circular, and that is similar to Fig. 1 of the Lindenblad patent in that it is not unidirectional, but it really is very different

because Fig. 1 of Lindenblad is bi-directional, or in the vertical plane, non-directional.

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X Q. 337. Incidentally, Mr. Carter, the patentee has been in the court room right from the beginning of the trial, has he not?

A. I think so; he may have been out part of the time, but he was in here when we started, and he is here now.

X Q. 338. He is that distinguished looking gentleman sitting at counsel's table?

A. He is sitting at counsel's table, and I think he looks distinguished.

X Q. 339. What are the limits by which you distinguish between a long wave and a short wave?

A. There are no specific limits; the terms are relative. The practice of the art is to put a convenient dividing line at about 150 meters, and say that waves longer than that are medium or long waves, and waves shorter than 150 meters but longer than 10 meters are short waves, and those shorter than 10 meters are sometimes called ultra short waves.

X Q. 340. In other words, they have the same difficulty with proper definition as between high and low voltage or current?

A. Yes, it is better if you want anything more than the [fol. 240] relative consideration to say what frequency or what wave length you are talking about.

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X Q. 347. That reminds me, you were at the defendant's Sayville station, weren't you, at the same time Mr. Hasell was there, pursuant to our invitation to come out and inspect the equipment?

A. Yes, I was one of the party.

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X Q. 355. Is Fig. 1 of the first Carter patent, No. 1,623,996, operative for short-wave transmission, in your opinion?

A. Yes, where the antenna is a short wave antenna.

X Q. 356. And just with the arrangement as shown in Fig. 1, what percentage of the reflected waves would be eliminated in your opinion?

A. That would depend upon the exactness of the match.

X Q. 357. What match, the match at coils 2-11?

A. 11-2, yes. You can get the standing wave down to the point where you cannot measure it with ordinary instruments.

X Q. 358. But if you were able to obtain a perfect match between the load 2 and the terminal 11, of the transmission line, it would be operative?

A. Not to the terminal 11, but to the surge impedance of the transmission line, if the antenna were a short-wave antenna.

X Q. 359. In other words, if the antenna was a short-wave antenna, and you could match the load coil 2 to the surge impedance of the line 10, it would be operative just the same as shown?

A. Yes. Of course, all the details of the system are not there. I mean, this does not pretend to show the details [fol. 241] of the source, but I see nothing in the teachings that would make it inoperative.

X Q. 361. You say it does not show the details of the source. It shows a source of current?

A. That is right.

X Q. 543. Now, will you please turn to the first Lindenblad patent No. 1,884,006, and, as understood you to testify with reference thereto, Fig. 2 of this patent merely illustrates the conical form of lobe that a wire, single-wire antenna will radiate?

A. It illustrates the largest lobe that will be radiated by a single long wire.

X Q. 544. A single long wire such as had been used prior to the date of the patent?

A. I do not know that they had been used in practice. In any event it represents what such a single long wire would do.

X Q. 545. And in Fig. 3, by using a pair of wires, the pattern of the larger lobe has been altered so as to concentrate the lobes into the form illustrated in the figure, and substantially cut off all waves above and below the plane of the wires, that is, above and below the plane of the paper, is that correct?

A. I wouldn't say it cut them off, but I would say it reduced them so that the principal radiation was in the plane of the wires.

X Q. 556. Now, the wires 14 and 16 of Fig. 3 of the first

Lindenblad patent are, as you pointed out, open ended, and they have standing waves on them?

A. That is right.

X Q. 557. You stated with reference to these wires, that they were several wave lengths long, in your direct examination. Insofar as having standing waves on them is concerned, does it make any difference how long the wires are [fol. 242] as long as they are open ended—that is, within practical limits?

A. One could have a wire so long in reference to the wave length that all of the energy applied was used either in the losses in the wire or in radiation, in which case, none would get to the remote end for reflection.

X Q. 558. You said that a wire a wave length long, open ended, would have standing waves in them?

A. I think that is the general practical case.

X Q. 559. And at one wave length long and open ended, they would still have standing waves on them, wouldn't they?

A. Surely.

X Q. 560. And at half a wave length?

A. Yes, as a general rule.

X Q. 572. Now, at page 1, line 33 of this first Lindenblad patent, the statement is made: "Furthermore, there is no radiation at right angles to the wire because although each half wave length oscillator might tend to radiate in this direction, the successive half wave length radiators are opposed in phase, so that at a distance from the wire the average effect is zero." Is that a correct statement, Mr. Hogan?

A. No, it is not full—it is not entirely correct. My understanding is that if the wire is an even number of half waves long, it is correct. If the wire is an odd number of half waves long, the extra odd section produces some radiation. It is small, of course, compared with the other.

X Q. 573. And this statement: "However, there is radiation in a direction intermediate the normal and longitudinal directions, and with a single conductor, this radiation takes place in the form of hollow cones having common axes in [fol. 243] the wire." That, of course, is referring to Fig. 2 of the patent, isn't that right?

A. That is right, and refers to the principal radiation, that is, the largest lobe.

X Q. 574. Then, again, at page 2, line 93, the statement is made: "It will be seen from the figure that these lobes are in the form of hollow cones having their apices adjacent and located in the conductor. In actual practice it should be kept in mind that there will be a number of different cones of various lesser magnitudes, and lying in different directions, relative to the longitudinal axis of the antenna, but for the sake of simplicity only the principal radiation is indicated, and its direction is indicated by the angle Alpha." Is that a correct statement?

A. I think it is generally correct.

X Q. 575. And that statement is true, for all antennae, isn't it?

A. It is true for all long single wires.

X Q. 576. Now, reference has been made several times here to this angle Alpha and the angle of staggering and like wise to the angle at which the waves are propagated in the plane of the wires. Does the patent state how to obtain that angle Alpha, or to determine that angle Alpha?

A. You are using Alpha for both of these?

X Q. 577. They are both of the same value, aren't they?

A. Yes, that is correct, I just wanted to be sure that we understood each other. There is no statement as to how that would be determined. That would be a matter of experiment for a particular case.

X Q. 578. We were discussing this angle Alpha, Mr. Hogan, and looking at Fig. 4, for example, or any of the [fol. 244] other figures for that matter, where staggered wires are shown?

A. Yes.

X Q. 580. The wires are staggered with respect to each other at an angle which is designated by the Greek letter Alpha?

A. Yes.

X Q. 581. And apparently, it is the same angle which the direction of the radiation of the waves bears to the axes on the antenna wire. It is correct that it is always the same angle?

A. That is my understanding, yes.

X Q. 582. You have just told me that although the patent has for its object the concentration of these lobes, which is attained only by the staggering as the important factor in conjunction with the excitation and phase opposition that the patent does not tell you how to determine that angle,

and that you can obtain it only by experimentation, isn't that just what you said?

A. Not exactly.

X Q. 583. Didn't you just say that you could obtain it by experiment?

A. Yes.

X Q. 584. Well, if you have anything else to say about it, please say it now.

A. What I had in mind was that the patent did not give a numerical determination of the angle Alpha for a particular case, and that having been shown the structure involving the stagger, as you brought out in this last question, the angle of stagger would be determined by measuring the experimental angle of principal radiation from the wire under that particular condition.

X Q. 585. Doesn't the angle of stagger determine the angle of radiation?

A. No; that is determined by the relation of the wire length to the wave length.

[fol. 245] X Q. 587. So that if you had the angle of radiation, which is determined by the wire length and the wave length, you would then match that angle by the staggered relation of the antenna, is that true?

A. In a sense. My idea is that the patent shows you that those are the same. Therefore, if you set up one of your wires and ran around that with an indicating instrument, to a distance sufficient to show the direction of a principal radiation, you could then stagger your wires at that angle, as shown in the patent, and you would have the cancellation, which is the feature of Fig. 4. That, of course, is again subject to practical modifications in the field because none of those theories apply to practical cases in exact detail. There are always compensating adjustments to be made by measurement.

X Q. 588. In other words, you do not know of any well-known formula for calculating that angle Alpha, do you?

A. I know the Carter formula now.

X Q. 589. That is the only formula you know, that is Carter's formula of Carter patent No. 3?

A. Yes, I think so. There have been approaches to it, but they have never been applied in this way.

X Q. 591. And the first time you ever knew of that Carter formula was when you saw Carter No. 3, I suppose?

A. Yes, that is correct.

X Q. 592. Then, am I correct in understanding that the angle Alpha as used in this Lindenblad patent is exactly the same angle Alpha that is referred to in the Carter patent, the third Carter patent in suit?

A. It works out to be the same angle. How complete Lindenblad's idea of it was mathematically or physically, I do not know.

[fol. 246] X Q. 593. We can go to the next step in this Lindenblad patent, which is represented in Fig. 5. And the next step is to eliminate the rear lobe and make the bi-directional antenna of Fig. 4 unidirectional, as illustrated in Fig. 5; that is correct, isn't it?

A. Yes.

X Q. 594. And that is accomplished by duplicating the antenna of No. 4 and spacing it in space and phase quadrature, is that right?

A. Along the line of propagation, as the space quadrature.

X Q. 596. And that is just exactly what was done in Figs. 3 and 4 of the first Carter patent in suit, isn't it?

A. It is exactly what is done when stated in such general terms as you have used.

X Q. 597. I believe that you also said at the time in discussing the features of the first Carter patent, that that was old and well known in the art even at that time?

A. Yes, in its most general terms.

X Q. 599. So that the second pair of wires which are spaced behind the first pair in proper phase and space quadrature in the direction of desired radiation acts as a reflector, is that right?

A. Well, it is often called that. The two are both driven, in this case, that is, they are both excited from the generator, so that the phases are kept accurately with relation to each other and, strictly speaking, the rearward antenna perhaps should not be called a reflector; on the other hand it is done frequently in the terminology of the art.

X Q. 606. Now, I call your attention to Fig. 6 of this Lindenblad patent. One difference between the arrangement shown in Fig. 6, and the arrangement shown in Fig. 7, is that the wires which are used as reflectors are separately [fol. 247] excited in Fig. 7, where as they are parasitically excited in Fig. 6, is that correct?

A. That is correct.

X Q. 607. They are equivalents, in so far as the reflector action is concerned, aren't they?

A. Quite approximately, they are. There are differences, but in general the operation is much the same.

X Q. 613. You, of course, know from your study of this subject and examination of the defendant's apparatus that each antenna is designed and used only for a specific wave length, don't you?

A. I think that is correct; for best results some modification is required whenever any substantial change in wave length is made.

X Q. 624. Now, Mr. Hogan, will you please refer to the second Lindenblad patent No. 1,927,522. As I recall your direct testimony, you confined your description largely to Fig. 2 of this patent. Do you recall whether you gave any description of Fig. 1?

A. No, I think I referred only to Fig. 2.

X Q. 626. Now will you please describe what is shown in Fig. 1?

A. Fig. 1 is similar to Fig. 2, except that no impedance matching device is shown, and except that the divergent wires are curved instead of straight.

X Q. 627. What kind of waves are there in Fig. 1 as described in the patent?

A. I thought the general description applied to both 1 and 2, either traveling or standing waves, and as a refinement, that the standing waves might be reduced. That is at page 1, line 38 and following.

X Q. 628. You recall, of course, the possibility of there being standing waves as specifically mentioned with respect to Fig. 2, and he therefore describes the use of an impedance [fol. 248] matching device?

A. No, I do not understand that, Mr. Darby. I thought the general description at the beginning of the specification applied both to Figs. 1 and 2 and the presence of impedance matching device had nothing to do with the existence or nonexistence of standing waves, but had to do with the question of whether the transmission line was long compared to the antenna.

X Q. 629. Now will you describe briefly Figs. 3, 4 and 5?

A. Briefly, Figs. 3 and 5 represent extensions of the diverging sections to a greater distance, so that the total antenna will be longer by adding to the diverging section, therefore, successive converging and diverging sections.

Fig. 3 shows that with curved wires, and Fig. 5 shows it with straight wires.

As I understand it, Lindenblad's thought in that connection was that where a very long antenna was desired it was uneconomical to keep on with the same pair of wires diverging, and therefore becoming far apart at a great distance from the apex. Consequently, he took advantage of the fact that he might bring them together again and start out. So that while he still required a large horizontal extension of ground to put the antenna on, he did not have to have so wide a strip of land.

X Q. 631. All of defendant's antennas here before the Court under charge of infringement employ standing waves on them as distinguished from the pure traveling wave type antenna?

A. They use standing waves. Of course, all antennas have a traveling wave component, but the defendant's antennas, like the plaintiff's, are standing wave antennas in the general sense.

[fol. 249] X Q. 632. As you have ably pointed out in connection with the consideration of the first two Carter patents, all of the defendant's antennae employ impedance matching devices, that is, all to which you have referred in this case?

A. Every antenna has an impedance matching device somewhere in the system.

X Q. 633. This patent we now have under consideration, beginning at line 3, says, "Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency, and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment".

So far as that statement is concerned, defendant's antennae all continue to suffer, do they not?

A. From the necessity of having an impedance matching device?

X Q. 634. Yes.

A. Yes, if that is suffering.

X Q. 635. And they are all critically tuned, aren't they?

A. Well, that would—I cannot say, because it would involve a definition of critical. They all are tuned, in any event.

X Q. 636. But they are tuned to a specific wave length?

A. Yes.

X Q. 637. Isn't that critical tuning?

A. Critical here means, as I understand it, that the change is less bothersome, less fussy than it would be in connection with antennas like the Model A. With regard to the fact that they are tuned to give an optimum result on a single wave length, if that is the meaning of critical, then defendant's antennas are critically tuned. With respect to the other meaning, they are not.

[fol. 250] X Q. 638. Then the patent continues, line 9, "It is an object of my invention to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency,". That expression means exactly what you have defined it to mean in connection with the first Lindenblad patent, doesn't it, that he can use the antenna as erected?

A. Yes, I think I explained it sufficiently there, that is, that the extent of adjustment necessary is less than in the case of the prior antennas.

X Q. 639. You do not mean to imply he could use this same antenna without reconstructing part of it at least and for a different wave length?

A. That would only be true in the strict traveling wave case. Let me make one other reservation when you said "without reconstructing a part of it", I am assuming that you are not excluding the idea that the antenna itself does not have to be changed, but that only the tuning adjustment of a coil or loop or whatever is used would have to be tuned in order to change the wave length. In the old antennas, where the di-poles were used and the antennas had to be exactly a certain fraction of a wave length in length and apart, there the structure had to be tuned. We are not misunderstanding each other on that, are we?

X Q. 643. But in defendant's antenna, the V type of antenna that they have at Sayville, here under charge of infringement, either the single V or the double V's, if you please, if they were going to change their wave length appreciably, according to you, they would not have to tear down the antenna and rebuild it or change the spacing between them?

A. They would have to change the spacing of the double [fol. 251] V's, but with respect to the single V's, they would

only have to retune, although if the wave length was changed very greatly on a short wire form, there would be some loss of power gain. We understand that?

X Q. 645. But if they wanted to obtain maximum power gain, they would have to change the angle of the V, wouldn't they?

A. For absolute maximum, yes.

X Q. 646. And the only way they could do that would be to tear down the poles, tear down the wires, position the poles at a different place?

A. That is a way of doing it anyhow.

X Q. 647. Do you know of any other way of doing it?

A. Yes, a variable antenna, that is, the antenna could be supported on a conductor between pairs of poles and moved in that way.

X Q. 648. I presume that you have in mind putting the poles on a truck and carrying the truck out, is that the idea?

A. Not at all. What I mean is, if you wanted to use an antenna, a single V antenna, successively at two different wave lengths and you wanted to get the angle correct for either of those wave lengths without moving the poles, which was your first suggestion, all you would have to do would be to support the end of each wire between the poles on a traveling trolley arrangement so that the wire could be pulled back and forth. I have done that very thing experimentally.

X Q. 649. And in any double V antenna, you have to change the special relation between them?

A. Yes, that would be more difficult to get the best cancellation.

X Q. 650. You would have to tear down the antenna and erect it in the proper spacial relation and move to a new position?

[fol. 252] A. Well, in some way or other, you would have to get the odd number of quarter wave length spacing between the antennas, whether you tore it down or not.

X Q. 651. After the patent has pointed out:

"The object of this invention is to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequencies," it goes on and states:

"A further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices."

Now, what kind of antenna is that?

A. That is an antenna of the pure traveling wave type, or one in which the length of wires is very great.

X Q. 652. So if you do not want to use an intermediate impedance matching device, you would have a pure traveling wave antenna. With that understanding, can you compare Figs. 1 and 2 of the patent, and tell me whether or not Fig. 1 by its absence of showing of an impedance matching device shows a traveling wave antenna as distinguished from a standing wave antenna?

A. No, because there is more to it than that. The point is whether any discontinuity, such as would occur at points 8 and 10 in Fig. 1 will cause reflection on the line, and whether or not the line is so long that you do not want that reflection because of a loss of efficiency in the transmission line that it involves. I think that is described at the bottom of the second column of page 1. It is not merely a question of whether there is reflection from the open ends of the antenna wires, but it is a question of whether there is reflection from [fol. 253] any point in the system that would increase the losses on the transmission line.

X Q. 655. And the patent then goes on:

"My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and which gradually diverge to a much wider spacing at their other ends."

Having in mind the sentence that I read first immediately above that, does that accurately describe Fig. 1?

A. It describes both Figs. 1 and 2.

X Q. 656. But Fig. 2 has an impedance matching device in it, hasn't it?

A. Even so, there is nothing that requires the omission of that in this description which you have read me.

X Q. 657. I asked you in the light of the preceding sentence which I read to you, which he wants to eliminate impedance matching devices. After he tells you he wants to eliminate impedance matching devices, then he says:

"My antenna consists simply of" what I read to you.

Does that describe Fig. 1?

A. Yes, it describes Fig. 1.

X Q. 658. And the two sentences together do not describe Fig. 2?

A. The second one describes Fig. 2, but the first one, that is something in which there is no impedance matching device, does not describe Fig. 2.

X Q. 659. Then my simple question is the two sentences together do not describe Fig. 2?

A. I do not know how to answer that, because half of it does and half of it does not.

X Q. 660. All right. And he continues:

[fol. 254] "In effect, therefore, the antenna consists merely of a gradually diverging extension of the conductors of the transmission line, and, in one aspect, the invention resides in the discovery that radiation may be obtained from a transmission line by gradually increasing the spacing between the wires of the line."

Does that describe Figs. 1 and 2 or Fig. 1 alone?

A. That describes the antenna portion of either Fig. 1 or Fig. 2.

X Q. 661. You consider in Fig. 2 that the radiating wires 2 and 4 are a mere continuation of the transmission line, do you, as shown?

A. As shown there, and as stated "in effect, therefore", which simply means for purpose of description.

X Q. 662. All right. Then the statement is made that "the desired radiation takes place in the direction of the axis of the pair of conductors".

That is another way of stating that it takes place in the bisector of the angle of the conductors?

A. It would include that, but I think it is a general statement as to the direction.

X Q. 663. Is there any difference between the axis and the bisector of the angle between them?

A. Geometrically speaking, there is none, but he points out about sideways radiation and so forth, and the complete description is that of radiation which is not strictly concentrated, but is radiated in the general direction of the axis.

X Q. 664. What justification have you in the disclosure in the patent, Mr. Hogan, for your last statement?

A. The statement immediately following the part that you read, at line 33, I think it is.

[fol. 255] X Q. 665. That is,

"Reflection will cause a standing wave instead of a traveling wave, and result in radiation sideways from the antenna."

Is that it?

A. Yes.

X Q. 666. And then it continues:

"Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet."

I think you described, in your direct examination, what is meant by a doublet?

A. I think so.

X Q. 667. And then it further states:

"However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention. It is not feasible, in the case of a transmitting antenna, to avoid standing waves by closing the end of the antenna with a surge resistance, because of the excessive losses which would take place therein."

Then he says:

"To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible. To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation" and so forth.

[fol. 256] He goes on to explain that it would take much spacing?

A. That is what you were talking about in connection with figures 3 and 5.

X Q. 669. Then he says:

"To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively."

Those are the figures 3 and 5?

A. That is my understanding. This part of his picture relates to that long narrow arrangement.

X Q. 670. In other words, he finds disadvantages in the arrangements of Figs. 1 and 2, and therefore suggests, as

a means of overcoming these disadvantages, the arrangements of Figs. 3 and 5. That is a correct statement, isn't it?

A. I think so, if you do not mean to exclude the fact that he also finds advantages in Figs. 1 and 2.

X Q. 671. I understand that is your opinion, with which I may tell you frankly we are not in accord. The defendant does not use, in any of its antennæ which you here charge infringe, anything like the arrangement shown in Figs. 3 and 5?

A. That is correct.

X Q. 672. Then at page 1, line 103, in effect, he says, that with the arrangement shown in Fig. 1, he does not have to employ an impedance matching device. That is a fair summation, isn't it?

A. No, I don't think it is.

X Q. 673. All right, let us go back to line 95:

"However, in actual practice I find that the refinement of an exponential curve is not essential, and that the con- [fol. 257] ductors 2 and 4 may be straight conductors strung between the points 8 and 12,"

such as are indicated in Fig. 2,

"No impedance matching device is necessary with this antenna,".

What is he there referring to, Fig. 1 or 2?

A. Both, I believe, it is in the general discussion of Figs. 1 and 2.

X Q. 674. And he would not need an impedance matching device with either Fig. 1 or Fig. 2?

A. As he points out below, if the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may be desirable to employ an impedance matching device between the transmission line and the antenna.

X Q. 675. All right. Now, what does he mean by short, and what does he mean by long? Does he state in his patent?

A. He points out—no, he does not distinguish between shorter lengths and longer lengths of wires that he pro-

poses to use, except that he recommends, at page 2, line 120 and 121, that the length of each antenna section should be of the order of magnitude of five to ten waves long.

X Q. 676. But he there refers to antenna wire, doesn't he?

A. You asked me about the transmission line?

X Q. 677. Yes.

A. Well, that would go back to the general idea of the transmission line that I mentioned before.

X Q. 678. He says that no impedance matching device [fol. 258] would be necessary if you had a short transmission line, is that the idea?

A. Yes, because then you would not be worried about the power loss in it.

X Q. 679. Let me ask you: Do you consider the transmission lines employed by the defendants to be short or long in the terminology of this patent?

A. Well, as we have just said, Lindenblad does not specify the lengths of his transmission lines, so I was answering as to lengths of the antenna. I pointed out in connection with the defendant's lines, that they vary from something over one wave length in a case which is not matched to, I think, as much as twelve lengths, where they are matched. There is no hard and fast line between long and short. The question is, if your losses are sufficient to make it worth while, you would like to use impedance matching to reduce them.

X Q. 680. Now, the antenna shown in Fig. 2 of this Lindenblad patent is bidirectional?

A. If standing wave component exists. If it has purely traveling waves, it will be unidirectional.

X Q. 681. Unidirectional along the axis of the V or bisector of the angle?

A. I assume in your question, and in my answer I used, bidirectional and unidirectional as describing whether the radiation was principally in the general direction of either side of the center line. I did not intend to have it taken in respect to the concentration on the bisector as a line. The fact is, there is sideways radiation in these Lindenblad antennas, whether mainly in one direction or extending in both directions.

X Q. 682. Now, how long would the antenna have to be to be a traveling wave or unidirectional antenna?

[fol. 259] A. That would depend on the wave length used, the resistance of the wire for the wave length, and the amount of radiation. In general, it would be quite long. Lindenblad says that the antenna sections may be five wave lengths to ten wave lengths long, so in the case of the multiple section type, the total might be 30 wave lengths long. I think that would give a very substantial reduction on the standing wave.

X Q. 683. I call your attention to page 2, line 103, where, in describing Figs. 3 and 5, he says:

"Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors."

That is equivalent to saying that radiation will occur substantially in the direction of the axis or bisector of the angle, isn't it?

A. Yes. You are simply asking me whether this is the bisector line. I do not see anything which requires the limitation of "the direction" in the strict "direction of", but I take it in "the general direction of", that is.

X Q. 684. Now, reading from line 96, preceding that,

"Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground;"

Will you please describe what is meant by this image in the ground?

A. That I understand to be a theoretical discussion based on the old idea that a wire above a perfectly conducting [fol. 260] sheet can be represented as to its effects in the space above that sheet, by a system in which a so-called image of the antenna is assumed to exist below the sheet. That, I think, is what this refers to. As a practical matter, in short waves, my understanding is, no such image can be had, so I do not agree with the application of that to the practical case here. I think it must be regarded only as a theoretical discussion from the short wave point of view.

X Q. 685. From the short wave point of view, as I understand it, it is your opinion that any representation of this theory of image reproduction in the earth is absolutely wrong?

A. You are putting it very strongly.

X Q. 686. I am, I intend to.

A. My feeling is that one may in general terms discuss the operation of an antenna structure and its image, so as to get an idea of the operation, so as to understand the device more completely. With respect to the attainment of that by short waves, which is what we are considering here, I believe that it is practically impossible, that is, impossible in practice—I don't mean only substantially impossible.

You can not have a simple, complete image over any ground or marsh or sea water which we have available to us for support of an antenna when the waves are short.

X Q. 687. Now we will take up the third Carter patent in suit, and I am concerned, for the moment, with the differences between this patent and the second Lindenblad patent we have just finished discussing, in so far as they are material to the issues of this case.

[fol. 261] The Third Carter Patent likewise shows a V antenna, that is correct?

A. Yes.

X Q. 688. And it likewise shows a reflector spacing and phase in quadrature, that is correct, isn't it?

A. You don't mean that is shown in the Lindenblad patent also, do you?

X Q. 689. No, that is shown in the first Lindenblad patent.

A. That is shown in the first Lindenblad, a parallel wire multiple antenna system, comprising two multiple wires, those pairs being spaced and excited in space and phase quadrature. In the Carter third patent, there are shown two V's, similarly placed and excited.

X Q. 691. Maybe we can make a short cut. The third Carter patent differs from the first Lindenblad patent, in that the third Carter patent uses a V antenna properly spaced and excited, whereas the first Lindenblad patent uses parallel wires properly spaced and excited; that is one point of difference between them?

A. One point of difference between them, yes.

X Q. 692. Is there any other point of difference between them?

A. Yes.

X Q. 693. What?

A. The disclosure of the angle between the wires for best operation, the showing of specific matching circuits, and so on. I would have to go through the whole patent to point out all the differences.

X Q. 694. That flows from the fact that the third Carter patent employs a V as distinguished from parallel wires; that is your first point of difference?

A. Well, all of these things go together. I would hesitate to say what flows from which.

X Q. 695. As I understand it, the difference between the third Carter patent, and the second Lindenblad patent is [fol. 262] that the third Carter patent gives you the proper angle between the legs of the V and employs a second V in proper space and phase excitation, is that correct?

A. That is correct, so far as it goes.

X Q. 696. Will you please refer to Fig. 2B of this third Carter patent? Does that represent features of the third Carter patent which differ from what is disclosed in the second Lindenblad patent?

A. Yes, when taken with the specification. The picture itself looks very much like the Fig. 2 of the Lindenblad patent, except for the omission of the impedance matching device.

X Q. 697. Well, in what respect does it differ?

A. As a picture, as I said, principally by showing the angle to the bisector.

X Q. 698. Figs. 2A, 2B and 2C are described on page 1, line 74, as indicating various forms of the fundamental unit of the present invention, and the only difference I understand from you between Fig. 2B of this patent and Fig. 1 or 2 of the Lindenblad patent 1,927,522, Lindenblad No. 2, is in the specific angle between the V?

A. That is the main difference.

X Q. 699. Is there any other difference?

A. Yes, as to Fig. 1, I was just about to say, Lindenblad's second patent, Fig. 1, shows curved wires which are not shown in these.

X Q. 700. And Fig. 2 of Lindenblad shows an impedance which is not shown in Fig. 2B?

A. Yes, we referred to the impedance matching device.

X Q. 701. But Fig. 2A and 2C do show impedance matching?

A. Fig. 2C shows it specifically; Fig. 2A shows a circuit which may be arranged so as to match impedance.

X Q. 702. And Fig. 2 of Lindenblad patent No. 2 shows a V-shaped antenna and not the curved wires, that is right, [fol. 263] isn't it?

A. Well, it shows a V-shaped antenna made of straight wires, and I suppose one could call even the curved wires a V-shape antenna, although it would not ordinarily be done.

X Q. 703. So that the only difference between Figs. 2C and 2A and Fig. 2 of the Lindenblad patent is in the precise angle between the legs of the V?

A. I think that is generally correct. I regard the fundamental unit of the Carter third patent antenna as shown in these three figures, 2A, 2B and 2C as a Lindenblad diverging wire antenna, giving the angle for maximum radiation along the bisector, and chosen in accordance with Carter's law relating to the angle and wave length used and the wire length used.

X Q. 704. The only figures of Carter's patent now under consideration which illustrate the complete antenna structure show in each instance the leg of the V, for example, Figs. 4, 5 and 11, the leg of the V, as composed at least of a pair of wires, that is correct, isn't it?

A. Yes; if I understand your question you are referring to the fact that Figs. 4 and 5 show the two-story arrangement that I described, and Fig. 11 the four-story arrangement, neither of which is used in detail by the defendant.

X Q. 705. That is right. Now, is there anything contained in this patent that places any limitation on the length of the antenna wires, that is, the legs of the V?

A. The general statement appears at page 1, line 29——

X Q. 706. I am trying to make time, Mr. Hogan. Can't you answer my question, direct your answer directly to the question?

A. Well, the question is so broad that it is difficult to give [fol. 264] an answer that would be correct without reference to the fact at least that the patent says that the wires are preferably longer than the operating wave length, and that the examples given are of wires five wave lengths in length and eight wave lengths in length.

X Q. 707. But there is no limitation to the advantages to be derived from the specific angle of this patent?

A. I couldn't say that without studying it from that point of view.

X Q. 708. You haven't studied it from that point of view?

A. Not from that point of view; I have always looked at it as a long wire patent.

X Q. 709. Then you would not be able to tell me whether or not I could use a one wave length, that is, an antenna with the legs of the V one wave length long, and obtain the benefits of the particular angle derived in accordance with the teachings of this patent?

A. You would obtain some of the benefits.

X Q. 710. As I recall it, Lindenblad, I think it is Lindenblad No. 2, likewise recommends an antenna length of five to ten wave lengths long, so that in that respect Lindenblad's second patent and the Carter third patent under consideration are in substantial accord, aren't they?

A. They certainly are not in disagreement as to the availability of wires of those lengths.

X Q. 711. Now, at page 4, line 27, the statement is,

"The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires [fol. 265] tilted away from the earth and towards the direction in which the beam of energy is to be propagated."

That means the same thing that was stated in one of the prior patents, I think the Lindenblad patent No. 1, that you would tilt the wires in this instance, the same as in the Lindenblad patent, upward, so that they would be at an angle to the earth's surface, is that correct?

A. Yes; which means that you would tilt the wires upward in order to increase the upward angle of propagation.

X Q. 712. Now, refer, please, to page 1, beginning at line 23, where it says:

"It is proposed to place these wires at an angle with respect to each other so that principal radiation takes place along the bisector of the angle. This angle, in general, corresponds to the angle of the principal cone of radiation of one of the conductors."

And that is the same angle that was referred to in the Lindenblad patent No. 1, that is, the first Lindenblad patent, by the reference character, the Greek letter alpha?

A. Yes, the same letter and the same angle.

X Q. 713. And the statement, in so far as it refers to the principal radiation being along the bisector of the angle, the statement is equally true to that extent, of the antennæ shown in the second Lindenblad patent, the V antenna?

A. Why, it is true more strictly in the case of the third Carter patent than in the case of Lindenblad's second, with respect to the concentration of radiation in the general direction of the bisector.

[fol. 266] X Q. 714. So that the difference between them in this respect at least is in degree, is that right?

A. It would be hard to define whether or not it is degree only. The practical results of the use of the Carter angle are very substantial. Certainly the concentration in the line of the bisector in the third Carter patent is much greater than the concentration along the line in the Lindenblad patent because in the Lindenblad second patent, the energy is distributed sidewise in a large part, but in the plane of the wires, as I have said, I think.

X Q. 715. All right. Now, the Carter patent says that the principal radiation takes place along the bisector of the angle between the two legs of the V antenna, is that a correct statement in Carter?

A. Yes.

X Q. 716. And is it a correct statement of Fig. 2 of the second Lindenblad patent that principal radiation takes place along the bisector of the angle; is that statement correct or incorrect for the second Lindenblad patent?

A. It is not correct that radiation takes place only——

X Q. 718. I didn't ask you that. Is it correct or not correct that principal radiation takes place along the bisector of the angle of Fig. 2 in the second Lindenblad patent in suit? Can you answer that yes or no?

A. No, because it will depend on the construction of the Lindenblad antenna.

X Q. 719. What do you mean by construction? What part of the construction will it depend on?

A. The wave length used, the length of the wire, and the angle.

X Q. 720. And isn't that equally true of the Carter patent?

A. Yes.

[fol. 267] X Q. 721 You certainly ignored that in answering my question in respect to the Carter patent.

A. In the case of the Carter patent you have been told how to get principal radiation along the line in large amounts, certainly, to get the very best effect. In the case of Lindenblad's antenna, the second patent, you are told how to use diverging wires to get radiation principally in the plane of the wires, and largely in the bisector. These antennas all have multiple lobes of radiation, and nobody can say in advance, or generally, what will happen for any specific case.

X Q. 722. Then you are drawing a distinction between the word "largely" in respect to the second Lindenblad patent and the word "principal" as employed in the third Carter patent?

A. No, I am not trying to draw any such distinction; I am trying to make it clear to you——

X Q. 723. Do they mean the same thing, "largely" and "principally"?

A. Certainly in many uses.

X Q. 724. And do they mean the same thing as used by Lindenblad and Carter respectively, or don't they?

A. There is no general answer with respect to Lindenblad; with respect to Carter, there is.

X Q. 725. There is some doubt in your mind, is there, that in the second Lindenblad patent, Fig. 2, as to whether or not radiation will be principally along the bisector of the angle of the legs of the antenna? Is there any doubt in your mind about that?

A. I think you are trying to include too many situations in a single question. What I am trying to make clear is that one may define radiation generally in the direction of a line——

[fol. 268] X Q. 726. You are certainly trying to do something other than answer my question.

A. I cannot answer your question because it involves——

X Q. 727. If you will just say so each time, when you don't understand my question, we will both save time.

A. All right, I am trying——

X Q. 729. Now, does the Lindenblad second patent in Fig. 2, and I refer to patent No. 1,927,522, have a structure which is highly directional and consists of a pair of conductors angularly disposed with respect to each other and in which radiant action occurs predominantly along the direction of the axis of the conductor system? Now, yes or no, it does or does not?

A. The answer is yes when "highly" is taken with reference to non-directional systems, but not with reference to more directional systems and when "along the direction of the bisector" is taken as meaning within the plane containing the bisector. I think that is what you mean.

X Q. 730. As far as any radiant action occurring predominantly along the direction of the axis of the system, does the Fig. 2 of the second Lindenblad patent show that or accomplish that? Does the antenna of that figure——

A. It shows a general picture of antennas which will accomplish that result.

X Q. 731. Will it or won't it accomplish it?

A. Some antennas represented by that figure will and some will not. In a strict——

X Q. 732. Does the patent tell you what is necessary to know in order to produce one that will and avoid producing one that will not?

A. It tells you how to produce an antenna in which the radiation is concentrated in the plane containing the bisector, [fol. 269] but as to concentration further within that plane to the line of the bisector, it does not.

X Q. 733. Wait a minute.

A. Well, I have already explained.

X Q. 734. I am going to get a simple answer to this question, Mr. Hogan. I do not care how long it takes. Does the patent, Lindenblad No. 2, and in Fig. 2 thereof, show, and does the patent describe everything that is necessary to know to be able to produce a V-shaped antenna in which the radiant action will occur predominantly along the axis of the conductor system—predominantly along the direction of the axis of the conductor system?

A. Yes, if you take "predominantly along the line of the axis of the conductor system" as a general statement and not one which requires concentration in the geometric line. That is all I have been trying to tell you.

X Q. 735. You didn't say it very simply, then. Is that equally true for Carter 3, the third Carter patent that we have under consideration?

A. The Carter third patent tells how to build a V antenna, which not merely concentrates the energy along the direction of the axis of the system, but within the plane of the wires in a beam along the line of the bisector.

X Q. 736. Then your answer is yes?

A. With the explanation I have given, yes.

X Q. 737. As I understand it, then, your answer is yes, that the Carter system or the Carter antenna, shown and described in the third Carter patent, will give you a system which will enable you to radiate, or in which the radiant action occurs predominantly along the direction of the axis of the conductor system?

A. Yes.

X Q. 738. Now, if you will turn to page 2, line 47, in the third Carter patent, beginning with line 47, there begins a [fol. 270] theoretical consideration in mathematical terms. Have you reviewed those considerations, as well as the formulæ shown at line 60 and line 70 and line 80, to determine whether or not it correctly explains how to obtain this angle between the legs of the V?

A. I think the explanation does give a general picture of the method Carter followed in determining the angle for any specific length of wire, and for any wave length on the wire.

X Q. 739. And the formulæ there given are correct?

A. So far as I know.

X Q. 740. Have you checked them to find out?

A. In a sense. That is to say, I have used V antennas having these angles, and determined that the maximum gain was had with these angles, within practical variations.

X Q. 741. When was that, in the last five or six years?

A. Yes.

X Q. 742. Now, these formulae given at lines 60 and 70 are another way of expressing the angle Alpha that we have referred to in connection with the first Lindenblad patent?

A. Well, they involve a similar angle, although in a different way.

X Q. 743. Will or will not these two formulæ be the angle Alpha of the first Lindenblad patent?

A. They will not be, they will lead to its derivation.

X Q. 744. In other words, you would use this formula to compute this angle Alpha of the first Lindenblad patent?

A. You can use it as a basis for that computation, and have in one case an odd number of half wave lengths, and in the other case, an even number of half wave lengths, but it does not state the angle Alpha explicitly.

[fol. 271] X Q. 745. Do you know of any other formula that could be used for that purpose?

A. No, I have made no study of that kind; that is my understanding of what Carter did, and whether it could be done in some other way, I can't say.

X Q. 746. So that so far as you know this is the only formula capable of figuring out the angle Alpha of Lindenblad 1?

A. No, I am afraid you misunderstood me. I meant that this formula could be used as the basis of deriving the angle Alpha, and the law connecting it to the wire length and wave length. Your last question was such as would imply the empirical formula of line 85, which gives an explicit value of the angle Alpha for any wave length and any wire length.

X Q. 747. This empirical formula at line 85, you meant to include with the first two formulæ?

A. No, I mean that the first two formulæ give a basis for the derivation of Alpha by maximizing or minimizing them as shown here, whereas the third formula at line 85 gives an explicit value of Alpha for any wire length.

X Q. 748. Then I will put it this way: Are these formulæ on 60 and 70 and the empirical formula at 85, are they the only formulæ that you know to enable you to calculate the angle Alpha in the first Lindenblad patent in suit?

A. Yes.

X Q. 749. They are. In this third Carter patent what importance does the height of the antenna above the ground have on this stated object of the invention? Does it have any bearing on it at all?

A. There are three or four objects stated; I am not sure I understand the relation to which or all that you are asking about.

X Q. 750. All of them. I am drawing no distinction. Does [fol. 272] any one of them, I assume it has a bearing as to some of them, tell me that?

A. Yes. We will have to see how Carter states it to answer that. If you want to ask me a specific question, I will answer it directly.

X Q. 751. Is it important to know the height above the ground for any antenna that you would erect under the third Carter patent so as to obtain radiation of waves and so that the principal radiation occurs along the bisector of the angle?

A. If you are referring to the fact that radiation in the plane containing the wires, and therefore containing the

bisector from the antenna alone, results in radiation at an angle of ten degrees or thereabouts upward in its direction of final propagation from the system, including the earth beyond it, which I referred to in my direct examination, then, the height above ground would have a bearing when that height is small compared to the dimensions of the antenna.

X Q. 752. Does the patent give you any instructions as to the height *of* the antenna should be above the ground?

A. Yes.

X Q. 753. Where?

A. It points out at page 3, beginning at line 44, that in practice where the height of the antenna is limited by economic causes and where it is desired to make ground absorption as low as possible, a good compromise is one-half wave length spacing, and then it goes on,

"For transmission of energy having a wave length of 17 or 18 meters, a good practical antenna may be had wherein the lower wires are about three-quarters of a wave length above ground, and the spacing between wires is one-half wave length. 80 foot poles or masts may be used to support the wires."

[fol. 273] That would apply to the two story case, and would put the lower pair three-quarters of a wave length above ground, and the upper pair one and a quarter wave lengths above ground.

Does that answer your question? I think you simply asked if I would say so.

X Q. 754. Yes, I think it does.

A. I did not include in my earlier answer the fact that this reflection effect which tilts the beam upward when the antenna is erected near the ground has no effect on the horizontal directivity we have been talking about. I think I explained that on direct examination, though.

X Q. 755. Now, reference has been made in this Carter patent as to this angle as designated by the Greek letter Alpha?

A. Yes.

X Q. 756. But I notice that where it is referred to in some of the claims of the patent, say, stated in formula form, as well as in page 2, this angle is referred to by the Greek letter Theta, is that correct?

A. Theta is used in the formulas at page 2, line 60 and 70, as an expression for an angle. There you are varying the angle for purposes of determining the desired value—one that gives maximum radiation. When you have determined that angle and you want to consider it, not in terms of variation of angle, but in terms of variation of wire length and wave length, then you use Alpha.

X Q. 757. For example, at Fig. 12, you show the angle as Alpha generally meaning the desired proper angle?

A. That is right.

X Q. 758. But in calculating it in the formula Theta is the unknown quantity, so to speak, that is the proper value of that angle Alpha?

[fol. 274] A. In one sense you are correct, you solve for the Theta which gives you the best condition, and then call that Alpha for that particular condition.

X Q. 759. If you will turn to Fig. 7 of the first Lindenblad patent No. 1,884,006.

A. Yes.

X Q. 760. There one pair of wires is excited by a tap connection to the transmission line?

A. Yes.

X Q. 761. Will you please explain to me what is the little loop that hangs down from the point 46, or rather right under the point 46, at the right hand side of the drawing? What is its purpose and what is its function, and how is it described?

A. It is described generally at page 4, beginning at line 3. I find no specific reference to the portion of the circuit to which you refer. The general purpose of the arrangement is for adjusting or tuning and matching the antenna system, as is explained in the part of the specification at page 4, lines 3 to 32.

X Q. 762. Now, in what respect, I ask you, does that arrangement of tuning and matching differ from the tuning and matching illustrated, for example, in Figs. 2A and 2C of the third Carter patent, if any?

A. Specifically in the adjustment of the so-called trombones shown near the meters 98——

X Q. 763. I am more concerned, Mr. Hogan, with this loop 12 at the bottom.

A. Well, as a mere loop it is much the same as the loop 14 in Fig. 2C of the third Carter patent.

X Q. 764. And the connection with the transmission line is the same, too?

A. They are across this loop, just as in Fig. 2C, although not shown variable.

X Q. 765. And you would have to connect the line 90, the [fol. 275] transmission line, across the loop at the right point, would you not, to obtain the proper impedance matching?

A. Yes.

X Q. 767. Now, I am concerned with the advantages that you have advanced for the third Carter patent, the first of which is that you obtain exceptionally high directivity per unit of the antenna system. In what respect does that differ from the first Lindenblad patent with parallel wires?

A. In that the directivity is greater, both per unit of the antenna and per dollar of cost. I think it is about 50 per cent greater per unit.

X Q. 768. And how does it compare with the second Lindenblad patent, with the V antenna?

A. Very considerably greater than the specific cases shown by Lindenblad.

X Q. 769. Lindenblad shows a specific case?

A. Yes, he recommends five to ten wave lengths and a spacing at the end of one-fifth of the wave length, and I think I gave in my direct examination a gain of about three for such a system.

X Q. 770. That would be very inefficient spacing?

A. No, not very inefficient, but very inefficient compared to what could be had now.

X Q. 771. Of course, the defendant does not employ any such spacing arrangement as that, does it?

A. No, the spacing is much greater at the ends of defendant's wires.

X Q. 772. And the second point is its low cost of erection and maintenance. Is there any difference in this second advantage over the first Lindenblad structure?

A. Yes.

X Q. 773. With the same length of wires, let us say?

A. Yes. This kind of antenna can be supported on three telephone poles that may cost a few hundred dollars apiece or, where a double V is used, by six, whereas the parallel [fol. 276] staggered wire antenna, if it is made vertical, for example, which is one common practical way of using it, the Model B, that requires two rather tall towers and,

where two bays of it are used, of course, four towers. Those towers run from something over a hundred feet to some two hundred feet in height depending upon the wave length that is used, and of course the cost of structures of that sort goes up very fast, something like the square of the height, and depends on the load on the tower, so that the supporting feature is mainly responsible for the saving in cost.

X Q. 774. Suppose you arranged the wires of the Lindenblad 1 horizontally, as is suggested in the patent, you would not need all these additional poles, would you?

A. You would need four poles in that case to support a single structure.

X Q. 775. So that, then, if you did that, the difference in cost between Lindenblad 1 and the third Carter patent would be the cost of one telegraph pole, is that right?

A. No, because you are leaving out the increased directivity, the relative——

X Q. 776. We are talking about cost.

A. We were talking about costs per unit effect, weren't we, or are we talking about cost per unit structure? It does not make any difference to me.

X Q. 777. I am talking about cost in exactly the same language that you used it in your testimony. You said nothing whatever about unit effect.

A. I spoke of it as giving a gain in directive effect and a gain in cost per unit.

X Q. 778. No, you did not. You said you are listing the advantages and the second advantage is its low cost of erection and maintenance.

A. All right, and that can be taken in terms of either [fol. 277] result or of unit. I am simply asking you what you want.

X Q. 779. How did you use it?

A. I have used it both ways now in discussing it with you.

X Q. 780. In terms of cost, how does the third Carter patent compare with the second Lindenblad patent?

A. In terms of cost per unit, they would be the same if the antennas built under them were the same. If the spacing were reduced in the second Lindenblad patent it might be possible to use only one pole to support the ends of the wires, though I think that would not be a practical case. I would say in general the situation was the same.

X Q. 781. The third advantage that you advance for the third Carter patent is its simplicity and stability of adjustment?

A. Yes.

X Q. 782. Have you exactly the same simplicity and stability of adjustment in the first Lindenblad patent?

A. No, it is not quite as simple. I think it is as stable.

X Q. 783. It is as stable?

A. I think so.

X Q. 784. But it isn't quite as simple?

A. No.

X Q. 785. How about the second Lindenblad patent?

A. That certainly is very easy to set up or adjust or tune, and it remains that way, as far as I can see.

X Q. 786. It remains that way?

A. Yes. Its main disadvantage is the relative inefficiency as there shown in detail.

X Q. 787. And the fourth advantage is the fact that it uses standing waves effectively and that there is no need to minimize them either by having exceptionally great length or by using terminal resistors. Is there any advantage there over the first Lindenblad patent?

[fol. 278] A. There is the advantage that the standing waves are used more effectively than in the first Lindenblad patent, but the general——

X Q. 788. In what way?

A. Due to the improved directivity of the system. But the general advantage to the extent that it is present in each structure is the same.

X Q. 789. And there is no difference in this respect between the third Carter patent and the second Lindenblad patent, is there?

A. Yes, there is a big difference there, because in the specific structure, and as far as Lindenblad knew, the standing waves could not be used effectively with his showing. That, I think I have pointed out, he considered as a difficulty which could be solved, that is to say, the antenna efficiency could be increased, the directive efficiency could be increased by reducing the standing waves, as he put it, as a refinement. Carter shows how the sidewise radiation could be not merely reduced, but reduced so that the ultimate efficiency was very high, and without eliminating the standing waves. That is what I am referring to.

X Q. 790. In Fig. 2 of the Lindenblad patent in suit there are standing waves?

A. It may be used either way.

X Q. 791. And you have so construed it in your testimony here?

A. Yes, I think so.

X Q. 792. Now, the fifth advantage is "Its adaptability to successful use with a wide range of lengths of wire and lengths of wave."

Is there any advantage in that respect in the third Carter patent over the first Lindenblad patent?

A. Yes, although it is tied in with the practical difficulty of building the first Lindenblad structure as the wave length [fol. 279] increases. I think this very simple system has got that very definite advantage in that it is more flexible and easily designed to fit a given condition involving considerable changes in wire length and wave length.

X Q. 793. What would be the difference with a horizontal antenna as suggested by the first Lindenblad patent?

A. The difference is principally in the simplicity of this arrangement which gets clear——

X Q. 794. Do not get off of the subject please. I am on the fifth point, its adaptability to successful use with a wide range of lengths of wire and lengths of wave.

A. Yes, and I am trying to put in words for you the fact that this is more adaptable, more flexible and more easily designed than the arrangement of the first Lindenblad patent.

X Q. 795. How about with reference to the second Lindenblad patent?

A. Well, I, of course, consider that the second Lindenblad patent includes this, so that specific cases of the Carter 3 antenna could also be called the Lindenblad second.

In the discussion we have had so far, I have not been doing that, I have been considering the Lindenblad second as that which existed in the practical art prior to Carter's third showing.

Now, with that understanding the adjustability or adaptability, rather, to a large range of wire lengths and wave lengths, is an advantage of the second Lindenblad antenna, but we must remember that its efficiency, as there shown, was low.

X Q. 796. Now, Mr. Hogan, the sixth point of advantage that you enumerated for the third Carter patent, is its high [fol. 280] radiation efficiency, which is usually 90 per cent or 95 per cent. Is that an advantage over the first Lindenblad structure?

A. They both have that advantage.

X Q. 797. How about the second Lindenblad structure?

A. The long wires will have individually high radiation efficiency, and the efficiency will be good; it may not be as high as that.

X Q. 798. And the seventh, "if the side wires are longer than about six wave lengths in length, it has a relatively high directive efficiency for a considerable range of wave lengths in any one structure, that is to say, that the preferred angle becomes less critical for the longer wires."

And the same is true for the Lindenblad second patent, isn't it?

A. Well, the third Carter antenna is within the broad description of the second Lindenblad, and if by that you mean to include it, it is true.

X Q. 799. I do not mean to include anything. Is that same advantage as you have stated with respect to the third Carter patent, does that apply to the second Lindenblad patent as well?

A. It would apply to a set-up built under the second Lindenblad patent, but is not pointed out how such an antenna could be built in the second Lindenblad patent.

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X Q. 810. Just one more subject and we are through, Mr. Hogan. In connection with this Exhibit E for identification, and in connection with any checking thereof that you may desire to do, I am making the statement to you for additional checking, if you desire, that while the distance between the wires in this instance, as illustrated in this exhibit is 2.04 wave lengths, which I understood you to [fol. 281] believe to be too wide that if this spacing of 2.04 wave lengths, between the parallel wires was increased to 3.09 wave lengths, that you would get perfect addition in the plane of the wires; and similarly, that if they were spaced 5.15 wave lengths, you would again obtain perfect addition of the waves radiating from the wires in the plane of the wires?

X Q. 811. Now, referring to Fig. 2 of the second Lindenblad patent, 1,927,522, will you obtain radiant action predominantly along the direction of the axis of the conductors 6, 2 and 4, irrespective of any angle of the legs of the V, 2 and 4?

A. You will obtain radiation predominantly along the bisector, as a general statement, that is to say, in the plane containing the wires, regardless of the angle, but you will get variations in the predominance along the geometrical line of the bisector depending upon the angle.

X Q. 812. So that at any angle from zero to 90 degrees or 180 degrees, you will obtain predominant radiant action in the direction of the axis or bisector of the angle?

A. I won't say in the line, but in the direction of the plane, that is to say, in that general direction.

X Q. 814. For example, if I draw an angle by erecting an antenna, and put the legs of the V at an angle such as illustrated on this sheet of paper that I show you, I will obtain predominant radiation in the direction indicated by the arrow on that paper in accordance with your last statement?

A. No; I do not know, I may have made it too broad. I have examined cases of the angle which are generally of the order of 45 degrees and less, but not such a wide angle as you show, and it may be that the general direction in that case would be substantially changed, even in the plane, [fol. 282] that is, there may be a dent in the plane of the wires.

X Q. 815. And would it make any difference with respect to the length of the wires of the V in that result?

A. I think the length of the wires would have to be taken into account, yes, surely.

X Q. 816. It is true, isn't it, in considering the radiation from a wire, say, for example, four wave lengths long, that you can consider it as radiation from a point in the wire midway between the ends, that is correct, as a matter——

A. That is one method of analysis, yes.

X Q. 817. Now, as I understand you, you don't know whether or not the radiation in the direction of the axis will be predominant for any angle between the legs of the V, you don't know?

A. That is for all angles?

X Q. 818. Yes.

A. No, it would be true, I think, only in the most general ones. There are so many cases, and they are so complicated that I haven't analyzed anything like a comprehensive group.

X Q. 819. Does the patent, if there is a possibility even that that general statement is not true, does the patent tell you what is the limit of angle between the legs of the V, where it will obtain the results of the patent or where it will not do so?

A. There are no statements in the second Lindenblad patent as to angle whatever and no numerical limits given. There are given a set of recommended cases, wherein the wires are five to ten wave lengths long, and the spacing is about one-fifth the length of the wire.

X Q. 820. Considering in this drawing that I now show you that the legs of the V are four wave lengths long, and that the angle between them is, the full angle, is 122 [fol. 283] degrees, and that it is provided with an impedance matching device between the load and the current source, and the legs of the V are excited separately in phase opposition, and that the usual transmission line is employed between the source of current and the antenna wires. In that arrangement the Vs gradually diverge so that there is a wider spacing at the open ends of the Vs than at their point of connection to the source of current?

A. Well, there certainly is a wider difference between the open ends than there is at the apex, but I wouldn't call that a gradually diverging V.

X Q. 822. What do you mean by a gradually diverging V?

A. I think there is no numerical limit to such a word as "gradually" but for practical purposes, I would expect the angle to be of the order of 45 degrees or less, certainly less than 90 degrees.

X Q. 823. And I think, I want to make it very certain, I think you said in your last answer that the wires, the open ends of the wire in this illustration are certainly widely spaced?

A. I said they were widely spaced compared to the spacing at the apex, yes.

Mr. Darby: May I have this sheet marked for identification?

(Marked Defendant's Exhibit F for identification.)

X Q. 824. My mathematical experts have advised me, Mr. Hogan, that in the arrangement shown on Exhibit F for identification, that rather than obtain radiation predominantly in the direction of the axis or the bisector of the [fol. 284] angle between the antenna, that you will obtain maximum radiation at an angle directly at right angles thereto and will obtain .01 of that amount of radiation in the direction of the axis or the bisector of the angle between the V, as illustrated in this drawing which I show you, and although I will ask to have this marked for identification only, at this time I will supply you with a copy of it, for your check, if you desire to do so.

Mr. Darby: I ask to have this copy of drawing marked for identification.

(Marked Defendant's Exhibit G for identification.)

X Q. 825. I am also advised in that connection, for any value that it may have to you in this matter, that if the angle was changed from 122 degrees between the legs of the V to 120 degrees between the legs of the V, that the amount of radiation in the direction of the axis or the bisector of the angle would be absolutely nothing.

Mr. Darby: That is all.

Redirect examination.

By Mr. Blackmar:

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R. D. Q. 831. You were also asked this morning with respect to utilization of a single V antenna for a number of wave lengths without change of the structure of the antenna. If you had a single V antenna set up on three permanent masts or poles and wished to reduce the wave length utilized therewith and yet maintain the proper angle between the wires, according to the third Carter patent, could that be done?

[fol. 285] A. Yes, because the angle is dependent upon both the wire length and the wave length; consequently, if, when the wave length was reduced, you will reduce the wire length by cutting off the ends of the wires proportionallly, the angle would remain correct and it would not be necessary to move the poles.

The question I was asked on cross-examination, I think, related to a case in which the angle was to be changed.

Mr. Blackmar: That is all. The plaintiff rests.

Defendant's Proofs

HARADEN PRATT, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Kolisch:

The Witness: I live in New York City. I am vice-president and chief engineer of the Mackay Radio & Telegraph Company, the defendant in this action.

There are two companies in the United States which are associated with the Mackay Company in the wireless business; one operates in the western part of the country, and the other in the eastern part of the country. Outside of the United States, there are companies in Spain, and in most of the important countries of South America and Central America, and Puerto Rico that operate properties that all have radio stations. My relation to those companies so far as the engineering and installation of radio [fol. 286] transmitting stations and receiving stations is concerned is that I am in charge of the engineering and technical maintenance of those plants. I have been engaged in the radio business as an engineer since 1914.

I was educated at the University of California and I graduated there in 1914. I became an engineer for the Marconi Wireless Telegraph Company of America, and I had to do with the supervision of construction of one of its radio stations at Bolinas and Marshall, California. After these plants were constructed I became an expert radio aide in the Navy Department at the Mare Island Navy Yard, and was transferred subsequently to Washington where, during the war, I was in charge of engineering and maintenance and design of all of the high power radio stations operated by the Navy Department. Subsequent to that, in 1920, I was placed in charge of the factory and engineering work for the Federal Telegraph Company and built a system for them, as well as operating the factory

in California. They were engaged in the manufacture of radio telegraph equipment, and they also operated a commercial radio station system, which extended up and down the Pacific Coast, connecting the various cities there by radio telegraph for commercial service. Following that, I did some exploration work and some business for myself, not related to radio.

In 1926, I built a system of communication for the Western Air Express, between Utah and California, when the air mail was instituted, and in 1927, I was placed in charge of development of radio aids for air navigation under the Commerce Department, Bureau of Standards, and I con- [fol. 287] tinued with that work under the direction of the Bureau of Standards until I accepted the position which I now hold, which was in 1928.

During this time, particularly while I was in charge of the radio work for the United States Navy, I had many occasions to inspect radio transmitting and receiving stations. I examined several hundred radio transmitters during this time.

I am an associate member of the Institute of Electrical Engineers and a scientific member of the Institute of Aeronautical Sciences and a fellow and director of the Institute of Radio Engineers. I am a fellow of the Radio Club of America; I am also chairman of some committees and subcommittees in connection with electrical standardization, sponsored by these various engineering societies, and the American Standardization Association. I have also served as technical advisor to the United States Government on the International Radio Station Conference in 1927, held in Washington, and also the engineering technical international organization, which operates under the auspices of the International Convention, which was held at Copenhagen in 1931.

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The antenna systems of defendant at Sayville which are shown in the various exhibits submitted by plaintiff and which are charged to be infringements in this case were installed under my direction.

There are many considerations underlying the construction of these antennae: first, the frequency or wave length, the distance over which you wish to transmit. As to this frequency or wave lengths, the Federal Government as-

[fol. 288] signs certain frequencies for certain stations and one is not permitted to operate on any other frequency, except ordinarily the frequencies that the Government assigns are in the neighborhood of those for which you ask. Those frequencies for telegraph transmission, speaking of these antennas, are in the so-called high frequency range.

Then there is the question of direction in which you wish to transmit; the question of the character of the topography between the transmitting and receiving stations; the general location of the transmission path geographically on the surface of the globe; the amount of land at your disposal; the topography of the land at your disposal; the electrical characteristics of the ground on which the antenna is to be built; the amount of directional effect, perhaps, that you wish in the particular case; the amount of undesired radiation with regard to the direction in which you wish to send desired radiation; the use of existing structures, if available, are taken into consideration, that you may have on your property; also the amount of money that you feel you can invest to justify the type of service for which you wish to use the antenna.

The Court: That comes first, doesn't it?

The Witness: Usually it does.

All these antennae and each of them is built to operate on one frequency and one frequency is used. I have had experience with these particular antennæ or with other antennæ installed by me or under my supervision in which the antenna was changed so as to take care of a different frequency; I made many such changes. I have made such [fol. 289] changes at Sayville. Antenna No. 11 was changed at one time for two reasons, change in frequency and also a change in direction. Antenna No. 7 was changed at one time, but that was for change in direction. Antenna No. 11 was an example of a change of antenna of the same type as are shown in these exhibits showing antennas Nos. 1 to 11, which are charged to infringe, where the change had solely to do with the operation of the antenna on a different frequency. If it had not been necessary to change the direction, the antenna would have to have been changed on account of frequency. In order to make this V antenna operate on a different frequency, the poles supporting the outer ends of the wires were moved so as to change the angle between the wires. As to the cost in any one instance

that I recall of changing the frequency, where it was necessary to change the antenna on account of a change of the frequency on which the antenna was operated as compared to the cost of installing a new V type antenna, I can only make an approximation. It might run from fifteen to twenty per cent., perhaps of the original cost. It was necessary in each case, in addition to moving the poles, to retune the antenna.

* * * * * * *

Referring to the antennas Nos. 1 to 11 at Sayville, I do not know of any case where radiation is propagated predominantly in the plane of the wire.

Cross-examination.

By Mr. Brown:

The Witness: I said in connection with the Sayville antennas that the signals were not propagated predominantly [fol. 290] in the plane of the wires. They were propagated in the vertical plane containing the bisector of the angle of the wires.

X Q. 129. What you mean by saying they were not propagated in the plane of the wires was that they were tilted upwards slightly from the horizontal plane of the wires?

A. If you are referring to the maximum direction or the direction of the maximum amount of radiation, they would be tilted up.

X Q. 130. I am referring to the same thing you were referring to.

A. That is what I was referring to.

I spoke yesterday about changing the direction of some of the antennas at Sayville. By "changing the directions" I meant the destination to which the signals were intended to go was changed from one place to another. I brought about that change of direction by moving the wires so that they would lie in a different place than they did before. In bringing about this change of direction, the bisector of the angle of the V was changed, of course, when the wires were changed. That was changed from the original destination to the new desired destination, so that the bisector of angle which formerly bore on one particular point was

changed so that the bisector of the angle of the V bore on the new destination.

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I was the engineer in charge of construction of the defendant's antennas at Sayville. I told the Court the considerations which impelled me to the choice of the particular antennas that were there. I recall stating the conditions that would confront one in designing any kind of an antenna system. That is what I meant in citing the conditions that [fol. 291] influenced me in designing those antennas. I can say that the antennas which were constructed were decided upon in view of all those considerations. The V antennas that I put up at Sayville were the most effective that I knew of at that time, for the amount of money that I wished to spend on them.

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To put up one of our double V antennas at Sayville it costs perhaps two to three thousand dollars. Whether that is the total cost of original installation depends on whether you are talking about book value or local cost. I mean local cost, that is the cost of labor and material.

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The designing of the defendant's antennas at Sayville, that is, those that are involved in this suit, was done under my direction. Mr. Kelley did not have any part in it.

I spoke of having seen a great many transmitting stations. As physical structures, the first ones that I saw that had an antenna in the form of a V with long straight wires, long in terms of wave lengths, and excited in phase opposition, were those which we erected at Sayville.

Redirect examination.

By Mr. Kolisch:

The Witness: I saw plans and drawings of antennæ having wires of the wave lengths such as described in my last answer in 1930. I saw them in our office in New York where they had been prepared for erection abroad. Those drawings were prepared by the Radio Engineering Department of the International Telephone & Telegraph Corporation.

[fol. 292] At the beginning of my cross-examination something was said about a tilt, referring to antennæ Nos. 1 to 11 at Sayville. In none of these eleven antennas are the wires tilted with respect to the horizontal.

LEO A. KELLEY, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

Q. 1. Mr. Kelley, where do you reside?
A. Jackson Heights, New York.
Q. 2. What is your occupation?
A. Consulting engineer.
Q. 3. Will you please state your education, training and experience which qualifies you to testify as an expert in this case involving the subject matter of matching impedances and antenna structure and operation?
A. Yes, sir.

I graduated from the Massachusetts Institute of Technology in 1918.

I specialized in radio engineering under the instruction of Dr. A. E. Kennelly, at Cruft Laboratory at Harvard University.

Along with my engineering training I had a complete course in problems connected with transmission lines and the transmission of energy over transmission lines, which included closing the end of the transmission line in surge impedance in order to prevent reflection of energy back over the transmission line.

Directly after my graduation from the Massachusetts Institute of Technology I was in the United States Signal [fol. 293] Corps over a period of approximately six months, and I spent part of the time at Yale University and also at Camp Albert Vale in continuation of the radio work in which I had received instruction at M. I. T.

From 1920 to 1925 I was a member of the engineering staff of the Western Electric Company, what is now known as the Bell Telephone Laboratories.

One of the first projects in which I was working was the Havana-Key West submarine telephone cable. It was on

this project that I first became acquainted, through actual experience, with the use of impedance matching transformers for terminating transmission lines.

In general, over that period, I was engaged in the development of high frequency signaling systems which were called carrier telephone and telegraph systems, and are also known by the popular name of wired radio. The late General Squire was the one who, I believe, gave them that name.

I had considerable experience with these high frequency signaling systems operating over a variety of transmission lines,—the submarine cable of which I have already spoken, and an aerial cable, and open wire lines. The latter type of transmission line corresponds to the type that occurs in the patents in suit.

In addition to this I carried on an investigation on the transmission of a multiplicity of signaling currents of different frequencies over the Havana-Key West submarine cable.

From 1925 to 1929 I was an engineer with the American Telephone & Telegraph Company in the Department of Development and Research. There again I continued my [fol. 294] work with the high frequency signaling systems, but I worked more intensively on the transmission of such signals over the long distance transmission lines of the American Telephone & Telegraph Company.

I also investigated, over a period of years, the interference caused by static or lightning induction on these long transmission lines while signals were being transmitted over them. I had at my disposal during this time, for the tests, something over 2,000 miles of these transmission lines.

From 1929 to 1932 I was on the engineering staff of the International Communications Laboratories, where I developed a new type of carrier telegraph system, which was installed between New York and Washington on the lines of the Postal Telegraph Company, and this system is still in commercial service.

From 1932 to the present time I have been engaged in general engineering and consulting work, mostly connected with signaling or communication systems.

I have been a member of the American Institute of Electrical Engineers and the Institute of Radio Engineers for a period of years.

I have presented a paper before the American Institute of Electrical Engineers, and also before the Radio Club of America.

I have also delivered two lectures at the Massachusetts Institute of Technology on the subject of a new method of designing electric wave filters.

* * * * * * *

Q. 42. Are you familiar with the defendant's antennæ as illustrated in the drawings which are here in evidence under [fol. 295] stipulation as correctly showing the defendant's antennæ?

A. Yes, sir.

* * * * * * *

Q. 53. Referring to the defendant's antenna, and we will take the simplest form, antenna 2, as illustrative in these respects of all the antennæ of the defendant; do you agree with Mr. Hogan that the transmission line is the line which extends from the transmitter to the points CD?

A. Yes, sir.

Q. 54. Do you likewise agree with Mr. Hogan that the energy radiating circuits in all these antennas consist of the wires AC and BD?

A. Yes, sir, they are the only part of the system which radiates to any extent.

* * * * * * *

Q. 242. With particular reference to the tuning arrangement employed by the defendant in its antennas, will you now refer to the first Lindenblad patent in suit. I call your attention particularly to Fig. 7 of the first Lindenblad patent as well as to Fig. 2C of the third Carter patent in suit, and I will ask you to please first describe the tuning arrangement of the Lindenblad patent, and compare it respectively with the third Carter patent in suit 2C, and the defendant's antennas arrangement.

A. Referring to the Lindenblad patent, a tuning arrangement is shown, marked 46, consisting of a trombone slide. That is the only difference, this being a minor difference, that instead of lengthening and shortening the legs by means of the cross bar, the cross bar is always connected

and the length is changed by sliding in and out like a trombone.

[fol. 296] The tuning is done by the lengthening and shortening of this member, and the points marked with circles right near the numeral 46 in the Lindenblad Fig. 7 correspond to the arrowheads marked 18, Fig. 2C, of the Carter patent, third Carter patent in suit.

Q. 243. If I may interrupt there, Mr. Hogan testified with respect to this loop of the Lindenblad patent, in answer to X Q. 763, "as a mere loop it is much the same as the loop 14 in Fig. 2C of the third Carter patent". Do you agree with that?

A. Yes, sir, that is what I have just described.

Q. 244. He was then asked, "And the connection with the transmission line is the same, too?

A. They are across this loop, just as in Fig. 2C, although not shown variable." The next question: "And you would have to connect the line 90, the transmission line, across the loop at the right point, would you not, to obtain the proper impedance matching? A. Yes." Do you agree with Mr. Hogan's testimony with respect to this loop of the Lindenblad patent?

A. Yes, sir, I do.

Q. 245. Now, will you compare the loop arrangement of the Lindenblad patent with the loop arrangement employed in the defendant's antennas in so far as it is used for the same purpose as used in Fig. 7 of the Lindenblad patent?

A. It is the same.

Q. 246. Have you any particular antenna in mind or does that apply to all of the defendant's antennas?

A. As far as I know, it applies to all.

* * * * * * *

Q. 292. Referring to defendant's antenna, in the case of any antenna employed by defendant, is the propagation of the radiant energy predominantly in the plane of the wires?

[fol. 297] A. No, sir, the radiation is sent out at a considerable angle, a substantial angle, to the plane of the wires.

Q. 293. Is that accomplished accidentally or as matter of design?

A. That is accomplished as a matter of design.

Q. 294. For a particular purpose?

A. Yes, for the——

Mr. Blackmar: If your Honor please, I do not know whether this witness has any knowledge of the design of these antennas. I don't know if this witness is qualified as to the design of these antennas.

The Court: I don't know; he testified to familiarity, and I suppose he knows.

Q. 295. What is the purpose of propagating the radiant energy from defendant's antennas at an angle to the plane of the wires?

A. The purpose is to make use of what is known as a sky wave so that, as is well known in short-wave radio systems, the energy can be reflected from the upper ionized layers of the atmosphere, and consequently sent to great distances.

Q. 315. Now, in so far as making a unidirectional antenna is concerned, will you please compare Figure 5 of the Lindenblad patent with Figs. 3 and 4 of the first Carter patent in suit, No. 1,623,996?

A. The same principle of spacing and phasing is employed in each case. For unidirectional radiation from a bidirectional system it is always necessary to space the individual radiators an odd number of quarter wave lengths apart in the direction in which it is desired to transmit or propagate any one of the two opposite directions and can- [fol. 298] cel in the other of the two opposite directions, the difference in time phase between the currents fed to the individual radiators being quadrature or 90 degrees apart and thus two conditions would have to be obtained, that is, that spacing and phasing would have to be obtained in order to change from bidirectional to unidirectional system, regardless of the character of the individual radiators that enter into the combination.

Q. 320. Will you please turn to the second Lindenblad patent in suit No. 1,927,522 and consider it with reference to its bearing on the antenna employed by defendant in so far as the subject matter of the patent permits you to do so?

A. The second Lindenblad patent refers to an antenna of the traveling wave type, of which defendant has none.

The nature of the second Lindenblad patent is very clearly contained on page 1 of the specification beginning with line 3, "Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment. It is an object of my invention to provide an exceedingly simple form of short-wave antenna which will operate over a considerable range of frequency, and a further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices."

The description of the present Lindenblad invention referring to that which he would avoid clearly indicates that [fol. 299] it is not for an antenna of the standing wave type, but an antenna of the traveling wave type.

An antenna of the standing wave type by its very nature should be tuned for best operation. Furthermore, some kind of impedance matching device should be used with a standing wave antenna for connecting from the transmission line to the antenna, and both of these elements which are so necessary in the case of the standing wave antennæ, in accordance with the passage I have just read, are to be avoided by the use of this second Lindenblad patent.

Q. 321. Will you look at these two drawings which are marked for identification as Defendant's Exhibit A? Did you hear Mr. Hansell's testimony as to the type of antenna that would give that type of pattern?

A. Yes, sir, I did.

Q. 322. Do you agree with his testimony in that respect?

A. As I recall it, he said it would be the radiation pattern from a traveling wave type antenna.

Q. 323. Do you agree with that?

A. Yes, sir, I do.

Mr. Darby: I offer the drawings in evidence.

(Defendant's Exhibit A for identification now marked Defendant's Exhibit A in evidence.)

Q. 324. Will you refer to the passage contained in the Lindenblad patent beginning at page 2, line 93, that portion

which refers to the image. I want you to discuss the subject of the image.

A. "In connection with Figs. 3 and 5,"—I am now read-[fol. 300] ing from the passage that you indicated, "the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground; we will then have two serially connected conductors (conductor 26 and the upper antenna leading to transmission line 24 in Figure 3). Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors."

He says in effect here that the two sides of the system, that is, the sides forming the V and cross back and forth, which are excited in phase opposition, may be replaced by what is the same thing, the omission of one side of this entire system, the side being omitted being replaced by the surface of the earth and the reflection of the remaining side in the ground, that is, the image of that one side in the ground will co-operate automatically in phase opposition so as to give substantially the same result as was obtained formerly with the two wires inclined at an angle to each other and excited in phase opposition.

Q. 326. Do you agree with the statement made in the Lindenblad patent?

A. Substantially, yes, sir.

Q. 327. Is or is not this subject of image or mirror in the earth an accepted principle in radio work, that you have been connected with?

A. Yes, sir; in fact, it goes back quite a long time and it has been almost the universal custom of those in the art to consider the ground to be a perfect mirror for electric [fol. 301] waves so that whatever radiation occurs from a structure above the ground, in operation one must consider the effect of its image in the ground either to enhance its radiation or to destroy.

Q. 328. During the prosecution of this Lindenblad patent, Lindenblad presented some claims to the Patent Office which the Patent Office rejected because of want of disclosure in the patent. As a result the patentee, Lindenblad, then the

applicant, wrote a letter to Mr. Brown of the Patent Department of RCA Communications, and that letter was made a part of the File Wrapper of the application in the Patent Office. One statement that is made in it is as follows:

"I believe it requires no argument that one-half of the system with an image in the ground functions as is claimed to obtain radiant action principally in the direction of a line perpendicular to the bisector of an angle between the conductors of half the system. The theory of images as first developed by Lord Kelvin has time and again been used and proved, especially in the radio art, and also in other branches of the electrical art. It is one of the axioms on which we build our theories of propagation and is an accepted fact."

Do you agree with that statement, Mr. Kelley?

A. Yes, substantially.

Q. 329. Now will you please direct your attention to the subject of the spacing between the open ends of the radiation wires of the second Lindenblad patent and its relation to the stated objective of the patent?

[fol. 302] A. Well, in the first place, Lindenblad in his patent desires to obtain a traveling wave type of antenna by making the antenna itself long enough so that as the energy is radiated out on the antenna, ultimately most of it will be consumed, and by making distinctions with the traveling wave antenna of the prior art, where terminations in the form of a resistance or other energy consuming devices were connected to the outer ends of the antenna, Lindenblad here desires to obtain the same result without such termination, by making the antenna wires long enough so that the energy is practically all radiated by the time it goes to the outer end of the wires, and consequently there will be practically nothing to be reflected and it is only by the mingling of the outward flowing energy and reflected waves on the antenna wires that the standing waves are produced, and in the absence of standing waves one has a traveling wave type.

In this case the energy is to be consumed on its way out. Such an antenna would have to be of considerable length, as Lindenblad recognizes.

On page 1, line 47, he states:

"To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible. To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation, and on the other hand, to keep the same angle of divergence necessitates so wide a spacing as to make the antenna structurally incon- [fol. 303] venient. To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively."

To paraphrase what he states in this passage, he recognizes that he must have the antenna long enough to consume a very large part of the energy. He recognizes also that merely to lengthen the antenna without at the same time keeping the spacing in the same direction to such an extent that this objective could be reached would certainly not be practical, because it would call for absurdly wide spacing at the outer end.

In order to avoid that, he arranges the wires as in Figs. 3 and 5 in the specification, crisscrossing them, that is, alternately diverging and converging with phase changing arrangements whereby he hopes to get a cumulative effect equivalent to what he would have gotten had he extended the wires straight on out the same length, and by this crisscrossing arrangement saving this extra space required by very long antenna wires.

Q. 330. Now referring to Fig. 2, for example, is there any relation between the spacing of the open end of the wires or the angle of the V and having the radiant action occur preeminently along the direction of the axis of the conductor of the system, in other words, must there be the proper angle of the V?

A. There should be a proper angle of the V.

Q. 331. Must there be a proper angle of the V?

A. There must be a proper angle of the V in order to obtain the radiant action largely in the direction of the bisector of the angle.

[fol. 304] Q. 332. Have you had prepared drawings illustrating a condition which might happen if the angle is not correct?

A. I have.

Q. 333. Will you please refer to these drawings which have been marked for identification Defendant's Exhibits F and G and describe what they represent?

A. Exhibit F merely shows diagrammatically the arrangement of the wires of a V forming an obtuse angle and excited in phase opposition.

Exhibit G shows, on an enlarged scale, the same V, that is, same angle V, each side of which is four wave lengths long, and on each leg of the V is shown the radiation pattern that would be obtained by the wire forming that leg of the V alone.

The radiation from this V-shaped antenna, as a system, that is, combined radiation from the two sides of the V, will be predominantly not along the axis of the system, but directly at right angles thereto; and, for comparison, if we represent the radiation at right angles to the axis of this system by the figure 400, the radiation along the axis of the antenna system would be represented by the figure 4. In other words, only one per cent in the direction of the axis of the conductor system, as compared with radiation in a direction perpendicular to the axis of the conductor system.

Q. 334. Is there or is there not some particular angle between the legs of the V at which you would obtain no radiation in the direction of the arrow?

A. Yes, practically zero radiation may be obtained by adjusting the angle of the V slightly from the position indicated in Exhibit G.

Q. 335. Would the change from zero radiation in the [fol. 305] direction of the arrow to a predominant radiation in the direction of the arrow be in a gradual scale from the zero position of the V to some other position closer together for the legs, at some narrower angle? In other words, is it an abrupt change or does that position——

A. Well, it is both an abrupt change and a gradual one, inasmuch as the minor lobes keep going in and out, so to speak, until quite a different angle is reached where addition is in the direction of the bisector predominantly.

Mr. Darby: I offer in evidence the drawing, Defendant's Exhibit F for identification and the enlargement, Exhibit G for identification.

(Marked Defendant's Exhibits F and G in evidence respectively.)

Q. 336. Referring to these two patterns, Defendant's Exhibit A, could one get the radiation pattern of Exhibit A with the antenna structure shown in Fig. 2, assuming that the wires are short enough to operate as a standing wave antenna?

A. Not at all. The result, even if the radiation were predominantly along the bisector of the system, would be bi-directional, that is, it would radiate strongly in two opposite directions, whereas the diagram shown on Exhibit A radiates predominantly in one general direction.

Q. 337. Could one obtain the radiation pattern illustrated in Exhibit A from an arrangement such as Fig. 3 or Fig. 5 of this Lindenblad pattern or Fig. 1?

A. If it could be obtained at all, it would have to be obtained with a very long antenna of the type of Fig. 3 or Fig. 5.

[fol. 306] Q. 338. How about Fig. 1?

A. If it were long enough.

Q. 339. What do you mean by long enough?

A. I really don't know how long, but certainly longer than anything that we are considering as regards defendant's antennæ which are of the standing wave type. It would be much longer than that.

Q. 340. Do you find any instructions in the Lindenblad patent as to the proper angle between the legs of the V antenna shown in Fig. 2?

A. No, I don't.

Q. 341. Do you find in the Lindenblad patent instructions as to the necessity for or how to obtain the angle between the legs of the V of Fig. 2 in order to obtain radiant action predominantly along the direction of the axis of the conductor system?

A. I don't.

Q. 342. Will you now turn to the third Carter patent in suit, No. 1,974,387 and first direct your attention to pointing out the difference between the disclosure of the third Carter patent and the disclosure of the first and second Lindenblad patents?

A. Comparing the third Carter patent with the first Lindenblad patent, the first similarity is in the element of the radiators with which the systems are constructed, the radiation diagram of Fig. 1-A of the third Carter patent, being the same representation as the radiation diagram from the single wire of the Lindenblad patent, Fig. 2.

In both cases the angle which the radiation makes with the axis of the wire is labeled Alpha. These two diagrams represent the same thing. They are simplified diagrams of which Fig. 1-B of the Third Carter patent is typical.

[fol. 307] In other words, the so-called minor lobes of radiation, the many smaller lobes in between the principal lobes are omitted for simplicity.

The radiation diagram of Fig. 1-B, which shows more in detail what the smaller form, shown in Fig. 1-A indicates, is obtained from a well-known formula which was developed by Abraham, and to which I shall refer later in more detail.

Q. 343. About when was it developed?

A. We have references to 1898. There was an article in 1898, and another article in 1901, both relating to the derivation of these formulae from two different standpoints, one was of quite rigorous derivation, and the other was derived using a convenient and practical assumption which is customary in the art today.

Q. 344. Proceed with your comparison, please.

A. So that the first Lindenblad patent utilizes the same radiation diagram as the third Carter patent. It utilizes the same principal lobes of radiation determined by the same formula, the only difference being that one set of lobes is used for obtaining a perfect combination in a desired direction by using parallel wires, which is the case of the first Lindenblad patent, whereas the third Carter patent utilizes the same radiation pattern and the same angle of principal radiation, but including the wires to each other, so that another set of lobes will add in preference to the ones that added when there were two parallel wires.

Q. 345. And in that respect the third Carter patent is the same or different from what was intended to be accomplished by the second Lindenblad patent?

A. It is the same as was intended to be accomplished by [fol. 308] the second Lindenblad patent.

Q. 346. And what does the Carter patent teach as to the plane of the propagated waves relative to the radiating wires?

A. The third Carter patent arranges the wires of the V in such a manner that these principal lobes of radiation, of which I just spoke, on the inside, so to speak, of one wire, with the principal lobe in the inside of the other wire, so it all will come together when the angle between the principal

lobe of radiation and the wire is equal to the angle to the bisector of the two wires, in other words, that these lobes will now combine exactly in the plane of the wire and along the direction of the bisector.

Q. 347. And is "along the direction of the bisector" or is it not, in the same plane of the wires?

A. Yes, the bisector of an angle is always in the same plane.

Q. 348. I believe you have already testified that none of the defendant's antennæ propagate waves in the same plane of the wires, but at an angle thereto. Is there any benefit obtained by doing that, and I now refer particularly to gain in propagation?

A. Yes, sir, there is. It is fundamentally necessary in working with short waves to direct radiation not in a horizontal plane direct, but at some angle to the horizontal, in order to carry on long distance communication successfully.

Q. 349. Have you had radiation patterns made illustrating the radiation in a direction along the bisector of the angle of the conductors, and what it actually is in defendant's antennæ, where the propagation is at an angle to the plane of the wires of the conductors?

A. I have.

[fol. 309] Q. 350. Will you please produce the chart of defendant's antenna No. 8 on which that sketch has been made and describe what is there shown?

A. Yes, sir; referring to the upper left-hand diagram, which shows what the radiation would be between the wires of a V, making an angle of 45 degrees with one another, there is shown the radiation pattern with minor lobes largely omitted.

Q. 352. In defendant's antenna No. 8, the angle between the legs of the V is 45 degrees, is that right?

A. That is right. This is the pattern that would be obtained in free space without obtaining the benefit of ground reflection.

Q. 353. Is that the pattern that would be obtained in the plaintiff's conductors?

A. That is a pattern that would be obtained in the plaintiff's conductors. The right-hand pattern shows the actual beam which is sent out and inclined at a substantial angle to the horizontal, the wires of the V being in a horizontal plane, consequently the main radiation takes place at an angle to the plane of the wires of the V.

Q. 354. Does the main radiation take place along the bisector of the angle?

A. No, sir.

Q. 355. In the left-hand figure does the radiation take place along the bisector of the angle?

A. Yes, sir.

Q. 356. Will you please explain the significance of the lower pair of diagrams as well as the significance of the 50 degree angle?

A. The angle of 50 degrees between the wires is the angle that would have been used had the instructions of the third Carter patent been followed, where actually in defendant's structure, the angle is 45 degrees. The reason for this [fol. 310] being that by using this angle different from the angle recommended by Carter, in his third patent, a larger lobe of radiation is obtained when an actual structure cooperating with the ground, its image in the ground, radiates at an angle inclined to the horizontal.

The radiation, the ultimate objective, so to speak, that which goes out to the receiving station, is greater by using the angle of 45 degrees with the same length of wire than it is by using the same V, but an angle of 50 degrees, as is recommended in the third Carter patent.

It was done at an apparent sacrifice as will be seen by comparing the two left-hand figures.

This upper left-hand figure represents the theoretical radiation, or in other words, the radiation in free space from the V of defendant, at an angle of 45 degrees, whereas the radiation in free space, using the angle recommended by Carter of 50 degrees, gives a somewhat greater theoretical radiation in free space, but it is not usable. One must build antenna structures with some relation to the ground, and if properly related to the ground, the ground could be made to enhance that radiation.

The right-hand figures show the reversal of the advantage that appeared to be obtained when the radiation was considered as free from the ground.

In other words, the upper left-hand figure, where the angle is 45 degrees and corresponds in defendant's antenna, the radiation is somewhat less in this direction than it is for the angle of 50 degrees in that same direction, but for the radiation which actually goes out, that is, the ultimate usable radiation, is greater as seen by comparing the two right-

[fol. 311] hand patterns where the distance numerically is 31 for the upper right-hand pattern and about 28.6 for the lower one.

Q. 358. If it has been suggested in this case, that by defendant's departure from the angle recommended by the Carter patent in suit by five degrees, the defendant has sacrificed anything in the efficient propagation of its waves, do you agree or disagree with any such suggestion?

A. I disagree.

Q. 359. And does this chart which you have been describing illustrate the reason for your disagreement?

A. Yes, sir, because the apparent sacrifice is turned into a real gain.

Q. 360. And when you say "apparent sacrifice", what do you mean? Do you mean apparent from theoretical considerations or from practical considerations?

A. I mean from practical considerations.

Mr. Darby: I now offer in evidence the chart referred to by the witness:

(Marked Defendant's Exhibit S in evidence.)

The Court: Did the patentee limit himself to that 50 degree angle, or was that just a suggestion?

The Witness: The patentee gives the proper angle for a given length of side in electrical length in Fig. 12 of the specification, and in this Fig. 12, the angle 50 degrees corresponds to the one that he draws a curve for, so that that is the angle which he says should be used.

Q. 361. Now, will you state whether or not the same is true [fol. 312] with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

A. Yes, sir.

Q. 362. Have you made a similar pattern and comparative diagram showing what the radiation pattern would be in direction along the bisector of the angle of the conductors in the plane of the wires, at an angle of the V of 35 degrees such as employed in antenna No. 2, and what it actually is and what it would be in both instances if the angle of the V were 35.6 degrees?

A. I have had such a diagram made.

Q. 363. And does the same relation that you have described with reference to defendant's Exhibit S apply to defendant's antenna No. 2?

A. The same considerations apply to antenna No. 2, yes, sir.

Q. 364. And are the same results obtained?

A. The same results are obtained, yes, sir.

Q. 365. And do you draw the same conclusions?

A. Yes, sir, the two upper diagrams here correspond to defendant, and the two lower, if the angle from Fig. 12 of the third Carter patent were used.

Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course to all of defendant's antenna?

A. Yes, they are typical.

Mr. Darby: I offer this other diagram in evidence, which has been referred to by the witness.

(Marked Defendant's Exhibit T in evidence.)

[fol. 313] Q. 367. With reference to the third Carter patent in suit, No. 1,974,387, does that patent teach in what plane relative to the plane of the wires predominant radiation is obtained?

A. Yes, sir, it does.

Q. 368. Just a minute. I had not finished my question. Does the patent teach in what plane relative to the plane of the wires predominant radiation is obtained by an antenna constructed in accordance with the disclosure of the patent?

A. Yes, sir, it does. It teaches that predominant radiation is obtained along the bisector of the angle formed by the wires, and in the plane of the wires.

Q. 389. If the wires were arranged horizontally to the earth, in what plant would the predominant radiation occur, as taught by the third Carter patent in suit?

A. As taught by the third Carter patent in suit, the predominant radiation would then occur in the horizontal direction in the plane of the wires which, as you say, are horizontal.

Q. 390. Will you refer to the third Carter patent in suit and point out the instances where the patent teaches this?

A. Referring first to page 1, line 62:

"To increase horizontal directivity, the arrangements of wires may be duplicated side by side."

This reference refers to an arrangement of the V where the wires are horizontal with respect to the ground and this

means that the directivity, that is to say, the predominant radiation is in the horizontal direction, in the plane of the wires.

[fol. 314] Again on page 1, I find still another instance, line 74:

"Figures 2a, 2b and 2c indicate various forms of the fundamental unit of the present invention wherein long linear conductors having standing waves thereon are disposed at an angle such that principal radiation occurs along the direction of the bisector of the angle."

Here again the same idea is expressed, namely, that predominant radiation, as taught by this patent, is along the bisector of the angle formed by the wires, that is, along the plane of the wires.

Again, on page 2, line 29:

"Now, if it is desired to radiate energy principally in the direction of axis X-X of Figures 2a, 2b, and 2c, the conductors, shown in Figure 1, should be turned an angle Alpha relative to the direction X-X; and, in order to increase still further the directional characteristic along the axis X-X, according to the present invention, two wires are used each of which makes an angle Alpha with the axis X-X on opposite sides of the axis in a fashion such that the axis and the pair of wires lie in a single plane."

This again means that the predominant radiation would be along the axis X-X, which is the bisector of the angle formed by the wires, hence in the plane of the wires.

Also on page 2, line 42:

"Consequently a pair of wires disposed at the angle [fol. 315] Alpha with respect to the X-X axis will have a radiation characteristic in the plane of the pair of wires of the general type shown in Figure 3."

This again means that radiation is predominently along the axis of the bisector of the angle formed by the wires, hence, predominently in the plane of the wires.

Again on page 2, line 97:

"The fundamental unit is shown in Figure 2a where a transmission line 10 supplies high frequency energy to a pair of wires A, B forming the angle 2 Alpha with each other. The angle Alpha is the angle made by one of the

conductors with the X-X axis along which it is desired that the radiators A, B, propagate energy."

Here again the same idea is expressed, that radiation is predominantly in the plane of the wires.

On page 3, line 71:

"That is, Figure 5 illustrates a system such as shown in Figure 4 duplicated in a direction along the X-X axis whereby, in a horizontal plane, a directional characteristic is obtained such as that shown in Figure 6 and, in a vertical plane a power distribution characteristic such as shown in Figure 7."

Q. 392. Will you just interrupt long enough to refer to Fig. 6, and point out how the figure there shown is consistent with that description?

A. Referring to Fig. 6, the designation below the figure is "Power Distribution, Horizontal Plane." The wires [fol. 316] of the structure which refer to Fig. 6 are in the horizontal plane, and consequently this means the radiation which takes place in the horizontal plane, that is, in the plane of the wires.

Q. 393. All right, proceed to the next one.

A. On page 3, line 86:

"Consequently, energy will be propagated principally along the axis X-X towards the diverging ends of the radiators."

The same idea of radiation in the plane of the wires is taught in that passage.

And, again, page 3, line 110:

"Thus, in Figure 8 each of the radiating units A, B shown in plan view is provided with a reflecting unit a, b. By means of branched transmission lines, as shown diagrammatically at T, each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves upon the units."

This again means that the radiation is predominantly in the plane of the wires.

Again, on page 3, line 124:

"By making the phase difference between each of the units equal to 2 pi S divided by Lambda, where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the [fol. 317] standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression."

This again teaches the same thing as the other passages which I have read.

On page 4, line 3:

"By suitable tuning and by suitable spacing of the radiating pairs of wires and reflecting pairs of wires, unidirectional propagation may be obtained in either direction along the bisector of the angle formed by the wires of each pair."

This again teaches that predominant radiation is to be obtained in the plane of the wires, and along the bisector of the angle formed by the wires.

And, finally, page 4, line 27:

"The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires tilted away from the earth and towards the direction in which the beam of energy is to be propagated."

The last passage which I have read, teaches again that radiation is predominantly in the plane of the wires and along the bisector of the angle formed by the wires, and if, as the passage indicates, it is desired to secure radiation at an angle to the horizontal, the patent teaches, in the pas- [fol. 318] sage I have just read, that one should tilt the whole structure so that the plane of the wires will no longer be in the horizontal but will be tilted so that the structure will point in the desired direction. That is, that the radiation in the plane of the wires will then be not horizontal but at the desired angle.

Q. 395. Now, with reference to this same subject matter and Mr. Hogan's treatment thereof in his direct examination, I will call your attention to Mr. Hogan's statement in

answer to Q. 71 (R. p. 177), which is, "With a V arrangement of that kind, the principal radiation of a pair of wires then takes place bidirectionally along the line of the bisector and principally in the plane of the wires." Was Mr. Hogan's understanding of the patent consistent with these passages that you have just read?

A. Yes, sir, that states clearly what the patent teaches.

Q. 396. Again, in answer to Q. 72 (R. p. 178), Mr. Hogan stated with respect to this Carter patent on this subject, "Carter's rule correlating the angle represented by alpha in Figs. 2A and 2B of the third Carter patent, correlating that angle with the wave length used, and with the length of the wire, taught how this principal radiation from the long diverging wire standing wave antenna could be concentrated not only in the plane of the wires, as occurred with the Lindenblad arrangement, but also still more effectively into a bidirective beam within that plane." Is that understanding of Mr. Hogan's as there expressed consistent with the statement in the patent?

A. Yes, sir, it is.

Q. 397. Finally, in answer to Q. 74 (R. p. 182), still in Mr. Hogan's direct examination, and referring to the Carter [fol. 319] third patent in suit, he stated, "Any one of these double V arrangements, that of Fig. 11, that of Fig. 5, or that of the model, has generally the radiation pattern in the horizontal plane which is shown by Fig. 6 of the patent. That is to say, all of them give primarily unidirective radiation along the bisector line." Is that statement of Mr. Hogan's consistent or inconsistent with the passages that you have read from the patent?

A. It is consistent with the passages which I have read.

Q. 398. Now, Mr. Kelley, do you know of any public statement made by the patentee, P. S. Carter, subsequent to the date of application for the third Carter patent in suit, wherein he stated contrary to the statements contained in the patent in suit that you have just referred to, as well as contrary to the testimony of Mr. Hogan that you have just referred to, that in both theory and practice horizontal radiation from a V antenna is zero?

A. Yes, sir, I have here a patent issued to Mr. Carter, No. 2,027,020, the filing date of which is September 15, 1932, and the issue date of which is January 7, 1936. In this patent, on page 1, line 3, he states: "In my United States patent No. 1,974,387," that is, the third Carter patent in this suit,

"granted September 18, 1934, there is described a V type antenna arrangement which is adapted to radiate energy directively. This arrangement comprises a pair of linear conductors which are long relative to the length of the communication wave and disposed at an angle in such a manner that when energized radiation occurs principally along the bisector of the angle." This passage refers to the third [fol. 320] Carter patent in suit and reiterates the teachings of the third Carter patent in suit, namely, that radiation will be predominantly in the plane of the wires.

However, on page 2 of this same recent Carter patent, line 30, it states, "In both theory and practice it has been found that the reflections from the ground are such as to always result in zero radiation horizontally at the usual communication distances from any short wave antenna. It has also been found " at radiation at angles in the neighborhood of 10 degrees to the horizontal is most effective at a distant receiver." This latter statement is contrary to the teaching of the third Carter patent.

Q. 399. Does the defendant follow the teachings of the third Carter patent in its commercial antenna relative to the radiation being in the plane of the wires?

A. No, sir, it does not.

Q. 400. Is the statement which you have just read from the subsequently issued Carter patent correct with respect to the direction of propagation of waves in defendant's antenna?

A. Yes, substantially so.

Mr. Darby: I offer this Carter patent in evidence, No. 2,027,020, granted January 7, 1936, on an application filed 15/9/32, and I might remind your Honor that that application was filed subsequent to the stipulated date of erection of defendant's antenna.

(Marked Defendant's Exhibit U in evidence.)

Q. 401. Can you illustrate on Defendant's Exhibit T the significance of this matter of direction of radiation relative [fol. 321] to the plane of the wires in so far as it affects defendant's commercial installation?

A. Yes, sir. The lower left hand figure shows the radiation diagram which would be obtained in accordance with

the teaching of the third Carter patent. This diagram is purely theoretical, that is, the radiation diagram shown here is from a pair of wires formed in a V entirely removed from the earth.

As I recall, Mr. Hogan stated in his testimony that by departing from the angle specified by Carter by a small amount that defendant thereby sacrificed some of the benefit to be obtained by using the angle specified by Carter. In so stating he was, of course, following the teaching of the third Carter patent, namely, that the all-important thing is the radiation from a pair of wires in free space.

The corresponding radiation pattern from a pair of wires in free space, using the angle actually used by defendant in this No. 2 antenna, it would literally be true that radiation is the direction in which the third Carter patent teaches would be less, but defendant is not relying on this theoretical radiation because any antenna structure must be built with some relation to the ground; and defendant makes use of that relation to the ground to obtain the real radiation pattern which is shown in the upper right hand figure and will be seen to be inclined to the horizontal, the wires in defendant's No. 2 antenna being in a horizontal plane, the radiation actually obtained is inclined at an angle to the horizontal, and no radiation occurs in the horizontal at all.

And furthermore, referring now to what would happen [fol. 322] had the angle specified by Carter been used and the antenna constructed a similar distance above the earth, the lower right hand diagram shows what would have resulted due to ground reflection. And it is seen by comparing the two right hand figures that instead of sacrificing any real radiation by virtue of using a different angle, a different angle is used deliberately in order to gain more radiation in the direction in which it actually goes out. That is, the lobe on the upper right hand diagram representing what defendant obtained by departing from the third Carter patent teaching is greater than would have been obtained with ground reflection and all contained in the antenna arranged using the angle specified by Carter.

Q. 402. And what have you to say as to the angle of predominant radiation to the horizontal as in Defendant's antenna No. 2 relative to the angle specified in the subsequently issued Carter patent now in evidence as Defendant's Exhibit U?

A. It is the same angle, namely, 10 degrees with the horizontal.

Q. 403. Will you state whether or not your foregoing explanation and comparison is equally applicable to defendant's antenna No. 8, the chart of which is in evidence as Defendant's Exhibit S?

A. Yes, sir, the same explanation applies, and the figures are in the same relative position as on the previous exhibit.

In this case, and I believe the No. 8 antenna was referred to specifically by Mr. Hogan, he stated that by departing from the angle specified by Carter, namely, 50 degrees for this particular length of wire resulted in obtaining 95 per [fol. 323] cent of the benefit to be derived by using the third Carter patent. Now, that would be true on an entirely theoretical basis, namely, where one does not consider the ground at all, in other words, where one only considers the left hand diagrams. And your Honor will see that this upper left hand diagram is one theoretically obtained in defendant's No. 8 antenna, and by comparing it with the theoretical radiation diagram obtained, had the angle specified by the third Carter patent, 50 degrees, been used, it is clear that defendant's theoretical radiation pattern would be somewhat shorter and also somewhat fatter than the one obtained by the angle of 50 per cent in the third Carter patent. As a matter of fact, however, when this antenna is erected above ground, the result obtained by defendant departing from the angle specified by Carter of 50 degrees and using another angle, namely, 45 degrees, is that something like 8 per cent more radiation is obtained than could be obtained with using the angle of 50 per cent, namely, by an apparent sacrifice in the theoretical radiation defendant departs from the teaching of the third Carter patent and obtains 108 per cent of the radiation that could be obtained had the third Carter patent teaching been followed.

Q. 404. In all of the results the left hand charts on Defendant's Exhibits S and T, is the pattern as there shown, the pattern which would be obtained if radiation occurred, predominantly or mainly in the plane of the wires?

A. Yes, in accordance with the teaching of the third Carter patent.

Q. 405. In view of the foregoing, will you state whether [fol. 324] or not in your opinion the defendant's antennas

operate on the same or on a different principle from that taught by the third Carter patent in suit?

A. Defendant's antennæ operate on a different principle from that taught by the third Carter patent in suit.

Q. 406. Will you state whether or not defendant's antennas function the same or different from the functioning of the antennas as taught by the third Carter patent in suit?

A. They function differently, because they take into account this ground reflection.

Q. 407. You mean what takes into account?

A. They take into account, so that the ultimate result is better by departing from the third Carter patent teaching.

Q. 408. When you say "they" in your last answer you mean the defendant's antennas?

A. Yes, I mean the defendant's antennas.

Q. 409. Now, with reference to the results, would you say that the results obtained by defendant's antennas are the same as or different from the results obtained according to the teachings of the third Carter patent in suit?

A. They are different from the results obtained by the teaching of the third Carter patent.

Q. 410. Now I want to direct your attention to this angle alpha and the Carter formulæ for determining it. First turn your attention to the formulæ appearing at line 60 and line 70 of page 2 of the Carter patent, and will you state just what is the difference between the two formulæ and what they represent?

A. The two formulæ represent the variation in field strength or radiation in going around a wire of an electrical [fol. 325] length which is a whole number of half wave lengths long by means of which the radiation diagram having these lobes of which I have already spoken may be plotted, that is, that these formulæ enable one to plot out the radiation diagram of the field strength for conductors having standing waves on them and which are an integral number, a whole number of half wave lengths long.

The first formula is used when the number of half wave lengths in the length of wire is an odd number, and the second formula is used when the number of half wave lengths in the conductor is an even number.

Q. 411. Then is it or is it not correct that both formulæ are used as presented by this patent for determining the angle alpha?

A. Yes, sir, because by taking these formulæ and using them in the way they are intended to be used, namely, to show how the radiation varies as one goes around in a circle about the wire, and when so used show that in a certain direction radiation is much greater than it is in other directions, this is indicated by the lobes or ears that one obtains by plotting this formula.

Q. 412. From your study of the art prior to the Carter patent in suit was that formula novel at the time of application for this third Carter patent?

A. Not at all.

Mr. Darby: I offer in evidence a folder containing the following publications: M. Abraham's article of 1898 in Annalen der Physik und Chemie, with translation; M. Abraham's article in Physikalische Zeitschrift of March 2, 1901, with translation; Bergmann's article of 1927, in Annalen [fol. 326] der Physik; article by Bontch-Broojevitch, 1926, in Annalen der Physik, with translation.

(Marked Defendant's Exhibit V in evidence.)

Q. 414. Will you proceed to point out this formula and discuss the Abraham articles, first two Abraham articles, with reference to this?

A. Referring first of all to Annalen Der Physik, 1898, Abraham article, I wish first to call attention, referring to page 8 of the translation, to point out the two formulæ which occur on page 2, at lines 60 and 70 of the third Carter patent in suit.

On page 8, or rather the last sentence on page 7:

"Therefore the radiation of the intensity of radiation along a meridian is expressed by the absolute magnitude of the function."

And then appears an equation:

"which as a first approximation is proportional to the cosines squared by the expression pi N over 2 times cosine Phi divided by sine squared Phi for the odd numbered, and is proportional to sine square of the expression pi N over 2 times cosine Phi divided by sine square Phi for the even numbered periods."

The last two formulæ which I have just read are the corresponding power formulæ from which the field strength

formula came by merely omitting the square in the terms, that is, cosine squared is cosine and the sine squared is sine.

It is very common practice in referring to radiation patterns and formulæ connecting them, sometimes to refer to [fol. 327] what is called the field strength, and other times to refer to the power. The reason one is the square and the other, that is the power diagram is the square of the field strength diagram, or is proportional to it, is that the power is derived by multiplying the field strength, the magnetic field strength by the electric field strength, which, in a wave in free space, are equal, and by neglecting units and merely stating this a proportionality, it is common to use either the term where the square occurs or the other term where the square does not occur, almost interchangeably. It is well known when you put the square in you mean the power and when you don't put it in, you mean the field strength, but they both teach the same thing; there is no confusion there.

Q. 415 Is it or is it not a fact that any engineer in the art with a formula stated in either the power or the field strength knows the other?

A. These formulæ are well known, so there would be no confusion whatever. By comparing these two formulæ with the corresponding formulæ in the third Carter patent on page 2, line 60 and line 70, and omitting the square for the reason I have given, the formulæ are identical with one other insignificant exception, namely, that the symbol used for the angle in 1898 Abraham article is Phi, whereas in the third Carter patent it is another Greek letter, Theta.

Q. 416. On what page of the original German article are these two formulæ that you have referred to on page 8 of the translation? Is it 471?

A. Yes, sir, these formulæ to which I have referred are the two formulæ occurring near the top of page 471.

[fol. 328] Q. 418. I get confused in my own mind which is power and which is field strength. Is it power or field strength that is given by this formulæ of Abraham's?

A. The power formula is the one given in the article by Abraham.

Q. 419. Will you please refer to any other Abraham article which you have which shows the same formula for the field strength?

A. Yes, sir, I have. And before going to that I might say that this first article to which I have been referring,

namely the 1898 article of Abraham, is a rather long article and highly mathematical. It treats of the problem in an extremely rigorous and fundamental way. He considers instead of a wire to begin with, a long wire to begin with, he considers a rather peculiar shaped arrangement or conductor for the antenna. It is known by the mathematical name of ellipsoid of revolution. It is actually egg-shaped. He does this so he can apply the Maxwell equations for dynamic equilibrium, and in working out the result which I have referred to, these formulæ for the radiation pattern, he does so by assuming this egg-shaped arrangement to be excited in some way so that it will produce natural oscillations, that it will vibrate electrically, so to speak, in various harmonics.

After going through a very abstruse treatment of the problem, which frankly at points were confusing to me, the problem being handled in an extremely abstruse mathematical way, he makes clear, however, what progress he is making, so that one knows what he means when he gets to the end, namely, he solves this problem, first, in a general way, then he discovers that there are conditions which he must fulfill in order to obtain the correct solution, but which [fol. 329] necessitates his making certain approximations. These approximations are followed successively through the article so that eventually he winds up not with an egg-shaped figure, this ellipsoid of revolution, but with an elongated conductor, which is the same thing as a long linear conductor; in other words, a straight wire, and the formulæ which he gives apply to the radiation pattern from the straight wire, the formulæ as I have already indicated being two in number one referring to the case when the conductor is an exact even number of half wave lengths long, and the other when the conductor is an exact odd number of half wave lengths long.

Then proceeding to the 1901 Abraham article, that is, the one in Physikalische Zeitschrift, 2nd of March, 1901, this article again teaches of a similar problem, but in this case, he makes certain assumptions which are generally made, and have been generally made certainly ever since his day by those skilled in the art in deriving the formula for the radiation patterns obtainable from conductors an integral number of half wave lengths long. In other words, he assumes here not this egg-shaped antenna, as in the 1898 article, but

he assumes at the outset a straight wire on which current is distributed sinusoidally throughout the length of the wire.

Referring to page 5 of this Abraham article, the 1901 article, referring to Fig. 2, and beginning at the top of this page, page 5 of the translation, he states:

"A wire EF (Fig. 2) of length 1 rises vertically upwards [fol. 330] from the earth. The earth is to be considered a perfect mirror for electric waves. The earth point E is a node of electric potential. The wire is now reflected with respect to the earth's surface and the potential distribution is chosen in such a manner that the opposite potentials are prescribed by two corresponding reflected points, one on either side, thus is the electro-magnetic field of the wire EF above the earth identical with that of the wire FL' of length 21 oscillating in free space."

What he means by that is that he is now considering a wire vertical and extending upwardly from the surface of the earth, and also that the earth's surface is a perfect mirror for electric waves, and that being so that the portion of the wire above the earth is reflected in the earth, so that it has an image of its own length, having the same current distribution, but having potentials which are of instantaneous opposite polarity.

Q. 422. Is that the same image or mirror that is referred to in the passage that I read to you with respect to the second Lindenblad patent?

A. Yes, he was referring to the same thing. And, as a consequence of this, Abraham takes the wire and its image as a wire twice as long off in free space, and neglects the ground entirely from then on. This results in the harmonics generated on the wire being the odd numbered harmonics. That is, in this article, the number of the half wave lengths in the length of wire that he is considering will be an odd number. Then he proceeds, assuming the current distribution that I have already referred to, that is, standing waves and sinusoidally distributed along the wire, and derives [fol. 331] the equations beginning on page 5, at the bottom of the page, and continuing on page 6, and also on page 7, until finally, on page 8, the formula is given, just below the middle of page 8,—namely cosine of the expression pi n over 2 cosine theta sub zero divided by sine theta sub zero, for the field strength radiation diagram for the long linear con-

ductor given in the third Carter patent on page 2, line 60. And in conjunction with this formula, referring still to page 8, the first full paragraph on that page.

"This electric magnetic field corresponds to a spherical wave, which spreads out rapidly from the middle point of the wire. We consider a sphere as r zero equals constant, and construct circles of longitude and latitude where we regard as the poles the points at which the extensions of the wire axis pierce the sphere. The magnetic force is everywhere in the direction of the circles of latitude, the electric force being oriented in the direction of the meridians. Both are perpendicular to the direction of propagation of the wave. The intensities of the forces vary with the latitude theta sub zero, according to the equation I have just referred to. Accordingly, for the fundamental oscillation (n equals 1) the amplitudes reach their maximum value at the equator (theta sub zero equals pi over 2)."

Pi over 2 is simply 90 degrees expressed in radians, that is, at right angles to the wire with the length of the wire for a half wave length long. Then at right angles to the wire will occur maximum radiation.

[fol. 332] I believe in the first Lindenblad patent, Fig. 1, there is shown a diagram corresponding to the half wave length radiator, and it will be seen the line, the vertical line between those lobes represents the direction of the wire, and the maximum radiation is seen to be in the direction at right angles to the wire.

"At the pole theta sub zero equals zero, the intensity is zero."

That is, lengthwise of the wire there is no radiation. That also is shown in Fig. 1 of the first Lindenblad patent to which I referred. This is universally true, of course, regardless of the length of the wire, there is no radiation lengthwise of the wire.

"For the fundamental oscillation the amplitude constantly diminishes from the equator to the poles. The harmonic oscillations, on the contrary, possess still other minima and maxima."

That is, when the length of the wire is not merely one-half wave length, but a plurality of half wave lengths, then, ac-

cording to the formula given here, the radiation pattern will be such that there will be many directions, corresponding, of course, to the number of half wave lengths in the wire, there will be many directions in which there will be maxima of radiation, in between which there will be zero radiation, and then again maxima radiations and so on, going around the wire.

By plotting out these formulae, it is observed that these maxima or lobes are not all of equal intensity, that is, the [fol. 333] length of the lobes is not the same in each case in going around the wire. That is, one wouldn't get a pattern looking like the arrangement of the petals of a daisy, but one gets a pattern in which the lobes nearest the wire, that is the first one you come to as you explore going around the wire, the nearest one you come to is always the largest lobe, and then, as is clearly shown by plotting these formulæ, the lobes are smaller and smaller and smaller, and then, again, they grow so that by the time one has reached the last lobe before coming along the length of the wire in the other direction, one will then obtain another large or principal lobe, and so on, around the wire.

Q. 423. Is that illustrated, the type of lobe you refer to, illustrated in Fig. 1b of the Carter patent in suit, the third Carter patent in suit?

A. Yes, sir, that figure, that is Fig. 1, represents such a diagram plotted using the Abraham formula when the wire is five wave lengths long. And as I have explained the principal lobes, that is the largest ones, which are apparent on expressing this equation in graphical form, correspond to the ones directed in the directions Y in Fig. 1b of the third Carter patent. The smaller lobes that I referred to, the ones not inclined so near to the wire, are the intermediate ones, so-called minor lobes.

Q. 424. Have you completed your consideration of this second Abraham article?

A. Except that I simply wanted to add that continuing where I left off, reading on page 8, namely, the last sentence on the page:

"The maxima lie in the latitude circles determined by [fol. 334] cosine theta equals plus or minus, M divided by N, when M is a whole odd number."

This merely states at what angles the indentations, that is, the angles at which zeros will occur between lobes as one goes around the wire.

Q. 425. In comparing the formulæ of the first Abraham article of 1898 with the formula given by the patent in suit, you called attention to the fact, I believe, that there was one difference, namely, that the angle in the patent in suit was referred to by the symbol theta, whereas the angle in the 1898 Abraham formula was called phi?

A. That is right.

Q. 426. What have you to say as to this respect in connection with the formula in the Abraham 1901 article relative to the formula shown in the patent in suit?

A. In the 1901 article Abraham uses the symbol theta to represent this angle just as Carter does in the formula shown at page 2 of the third Carter patent.

Q. 427. Is that likewise true with respect to the claims of the patent where the formula is included in the recitation?

A. Where these same formulæ are included, also apply.

Q. 428. Is or is it not the formula of Abraham identical in expression with the formula given by Carter?

A. Yes, sir, the formula occurring on page 2, lines 60 and 70.

Q. 429. Are his symbols identical or not?

A. Well, as I have indicated, in the 1898 article the symbol for the angle is referred to as phi, whereas in Carter's formula it is called theta. It is insignificant what you call it, but it so hapepns that in the 1901 article Abraham also calls it theta.

[fol. 335] Q. 430. In the 1901 article of Abraham, does he there express the formula in terms of field strength?

—. He there expresses the formula in terms of field strength, yes, sir.

Q. 431. Is it or is it not a fact that the Carter patent expresses the formula in terms of field strength?

A. The Carter patent expresses the formulæ here in field strength.

Q. 432. Are the formulæ of the Abraham article identical with or different from the formula of the Carter patent in suit in so far as their meaning is concerned?

A. The formulæ given in the Abraham articles and the formula given in the third Carter patent are not different

at all in so far as their meaning and significance are concerned.

Q. 433. Will you please refer to the empirical formula of the Carter patent in suit and state in what respect, if any, it differs from the other formula to which you have already referred?

A. I believe I can best answer that question by indicating in what manner this empirical equation is arrived at. I have already referred to the fact that when plotting the Abraham formula it is found that all of the lobes are not equal in extent; and that especially as the wires get longer and longer, the lobes inclined nearest to the wire are decidedly larger than any of the other lobes. In other words, it indicates that the application, the graphical representation of the Abraham formula, shows that a single wire excited in its harmonics is a decidedly directional radiator and that this directional characteristic is in the direction of these principal lobes, the ones I have mentioned being inclined nearest to the wire and the ones that I have stated as being [fol. 336] shown by plotting the Abraham formula. And since the greater part of the radiation from the single wire occurs in the direction of these principal lobes, that direction is, of course, given by the Abraham formula simply by plotting the angle and may be determined graphically in that manner.

It may also be obtained by mathematical operation of determining, in accordance with the principle of differential calculus, maximum values, and if it is done that way you would still have a graphical step to perform and the result would be the same anyway.

What is done in order to arrive at angle alpha, which is this angle where the Abraham formula has a maximum which is greater than the other maxima, in other words, where the Abraham formula has a large lobe in comparison with the smaller ones, that particular angle is the angle alpha referred to in this third Carter patent, and in arriving at an empirical formula, one takes a wire one-half wave length, finds out the angle in which this maximum occurs with the Abraham formula and plots a point; then he takes two halves, three halves, four halves, and so on, in other words, every half wave length, and in each case determining from the Abraham formula at what angle this principal lobe of radiation takes place, and plots that result, namely, the

correlation between the length of the wire, since it is half a wave length, one, one and a half, and so on, plots that against the length of the wire, this angle, which Carter designates as alpha, and through this series of points draws a smooth curve, remembering, of course, that the formulæ apply only to discrete points.

[fol. 337] Q. 434. Is this angle that Carter designates as alpha in that instance the same as theta in the formula?

A. It is the same as a particular value of theta, namely, the value at which this maximum lobe occurs, the nearest one to the wires. Then the empirical formula comes from this, having drawn a curve, smooth curve, through these points, in other words, disregarding whether or not anything happens in between these points to which the formula doesn't apply, but merely drawing a smooth curve through these points, then by methods well known to engineers, deriving a curve, an equation, rather, which fits the curve as near as possible practically. And the result of that is the empirical formula given on page 2, line 85.

Summarizing what I have said, this formula is an artificial equation, you might say, given to a curve drawn through the discrete points for the different lengths each of a number of half wave lengths at which the angle of theta is in the principal direction.

Q. 435. *Is or is not the correctness of the empirical formula* given on page 2, line 85, dependent upon the correctness of the curve illustrated in Fig. 12 of the Carter patent?

A. As near as I can tell, the curve in Fig. 12 of the Carter patent is the curve of the empirical equation. It is a simple plot of that equation, as near as I can tell.

Q. 436. Does or does not the accuracy of the curve illustrated in Fig. 12 of the third Carter patent in suit depend upon an assumption with respect to its accuracy between points representing half wave lengths?

A. It depends upon the assumption that the Abraham [fol. 338] formulæ, from which it is derived, are equally applicable at other lengths than an integral number of half wave lengths.

Q. 437. Have you made an enlargement of Fig. 12 of the Carter patent in suit on which you have likewise plotted the curve according to the Abraham formulæ?

A. Yes, I have.

Q. 438. I notice that there is a curve on there marked Bruce. For the present will you please ignore that? Describe what you have thus shown.

A. The curve labeled Carter angle followed by the empirical equation, which occurs on page 2, line 85 of the third Carter patent, is actually the curve of Fig. 12 of the third Carter patent.

The curve labeled Abraham angle was added by me to indicate the comparison between the curve obtained with the empirical formula of Carter and the actual curve obtained by plotting the Abraham angle.

By comparing the two curves it will be seen that the empirical curve fits rather well the curve for the Abraham angle above lengths of approximately two wave lengths, whereas, using that also as a rough dividing line for shorter lengths of wire, the curve showing the Abraham angle departs from the Carter empirical curve by the amount indicated.

Q. 439. And on which side lies accuracy, the Abraham formula or the empirical formula?

A. The Abraham angle, of course, is the one which is the proper one to use. The departure of Carter's curve merely indicates the extent to which the equation does not fit along that portion of the curve, the extent to which it does not fit the curve obtained by drawing through points [fol. 339] obtained by substituting in the Abraham formula, that is, the so-called Abraham angle curve.

Q. 440. As a matter of fact, does the empirical formula or the curve of Fig. 12 of the Carter patent correctly show what actually occurs with wires, radiating wires that are not exact multiples of half wave lengths?

A. It doesn't show exactly what the curve should be for lengths which are not exact multiples of a half wave length. All of this is based on the assumption that the length of the radiators is an integral number of half wave lengths and consequently one cannot go beyond the assumptions, and for that reason it is not true to say that this is accurate for points in between.

Q. 441. Would that be shown by what is referred to as radiation resistance curves?

A. Well, indirectly it would be shown by the radiation resistance curves.

Mr. Darby: I offer in evidence the enlarged Fig. 12.

(Marked Defendant's Exhibit W in evidence.)

Q. 442. Will you please refer to the subject of radiation resistance curve and its bearing on the matter under consideration? First let me ask you, are you familiar with the article of Carter, Hansell and Lindenblad in the Proceedings of the I. R. E. here in evidence as Plaintiff's Exhibit No. 20?

A. Yes, sir, I have read it.

Q. 443. Do you or do you not understand this article to constitute a more detailed description of the subject matter of the patents in suit?

[fol. 340] A. I understand this article to deal rather in detail with the subject matter of the patents in suit.

Q. 444. Is there any radiation resistance curve shown in this article purporting to represent antenna of the character referred to in the third Carter patent?

A. Yes, sir, on page 1803, Fig. 21. I might explain, first of all, I, having said previously but indirectly, radiation resistance shows up this difference, or, I will put it this way: The fact that the results of the Abraham formulæ are applicable only to wires an integral number of half wave lengths long, the reason for so stating is this, that the Abraham formulæ showing the radiation distribution or pattern about a long linear wire, those formulæ are used in order to determine the radiation resistance of the long linear wire.

The curve shown in Fig. 21 of the I. R. E. article, on page 1803, the upper curve is labeled "Radiation Resistance". The figure is entitled, "Radiation Resistance and Power Ratio of the Long Wire Radiator," that is, a single wire electrically long with standing waves on it. The radiation resistance curve is the upper curve, and it is shown as a smooth curve, that is, although it is curved, its curvature is always in the same direction. It is a smooth curve, and evidently was plotted from discrete points for which the radiation resistance was determined, those discrete points being for exact multiples of a half wave length and then, as in Fig. 12, referring to angle alpha in this figure, draw-

ing a smooth curve through those points and obtaining the result shown in Fig. 21 in the upper curve.

Q. 445. Will you refer in this connection—and we will [fol. 341] come back to this diagram—will you refer in this connection to the article of Bontch-Broojevitch that is in evidence for its bearing on this particular subject, referring particularly to page 438 of the original German, at page 9 of the translation?

A. Referring to page 15 of the translation, formula 29, given just below the middle of the page, corresponds to the formula 27 on page 1802 of the I. R. E. article. The only difference here is Bontch-Broojevitch includes a factor NI^2 before the brackets in equation 29, merely for the purpose of dividing up the power radiated in these half wave length oscillators, in which fashion he regards the long linear wire, half wave length oscillators M to N, and to divide it up in terms of how much power is radiated from each one of these.

In order to express this as radiation resistance, all that is necessary to do is divide both sides by NI^2, which is quite clear from the meaning of the formula. And when this is done, it is identical with equation 27 of the I. R. E. article that is on page 1802. In the brackets of equation 29 in Bontch-Broojevitch, on page 15 of the translation, the letter E designates what is known as Euler's constant, which is equal to .5772. In the equation 27 in the I. R. E. article, instead of writing E for this term, the actual value is given.

Following equation 29 of the Bontch-Broojevitch article, it says:

"Where CI, as before, is the integral cosine, the value of which is not far from zero. The following table gives the values of the resistance for the various values of n."

[fol. 342] Now, there follows a table in which the upper row or the successive numbers 1, 2, 3, 4, 5, 6, 7 and 8, and they are the values of n, that is, the number of half wave lengths in this linear radiator.

The second row gives the radiation of resistance due to each one of these half wave length oscillators; as the number increases, that is, you correlate the upper row with the corresponding value immediately below it. So that to convert this into the total radiation resistance of the whole radiator, one multiplies the lower figure by the upper one.

For example, where n equals 1 the radiation resistance is 72.5 ohms, one times 72.5. Where the number is 2 it is 2 times 47 or 94 ohms, for the whole radiator, and so on.

Plotting these values, one obtains discrete points, a point for each half wave length, and these points, with the exception of one, in which there appears to be an error at No. 7, all of the other points would fall on the radiation resistance curve shown in Fig. 1, on page 1803 of the I. R. E. article.

Q. 446. Now, have you had plotted a radiation resistance curve showing what departure, if any, from one taken on the half wave points would occur for antenna wires having radiators which are intermediate between half wave lengths in lengths?

A. Yes, I have.

Q. 449. Will you please produce the curve and describe it?

A. Yes. The radiation curve which I had computed shows what actually happens at intermediate points, that is, points which are not an integral number of half wave lengths long.

If a smooth curve is drawn through the radiation resistance points for the integral number of half wave lengths [fol. 343] long, then that curve would follow generally the top of impedance of the radiation resistance curve which I am now referring to.

It shows at once the error that one falls into in going beyond the assumptions upon which the original work was done, that is the Abraham formulæ, and radiation resistance equations derived from the Abraham formulæ applied only to half wave lengths—two radiators having an integral number of half wave lengths in length.

This curve which I am producing shows that the radiation resistance falls off to a substantial amount in between these values of half wave lengths, that is, the valleys along this curve represent the radiation resistance that would be obtained if a wire were an odd number of quarter wave lengths long, rather than an integral number of half wave lengths long.

Q. 451. And the quarter wave length would be the maximum deviation from intervals of half wave lengths?

A. Clearly, because if you go beyond a quarter wave length the distance in one direction, you are approaching the next half wave length point.

Mr. Darby: I offer the chart that the witness has referred to in evidence.

(Marked Defendant's Exhibit X in evidence.)

Q. 452. Now, I direct your attention to the fact set forth in the stipulation of defendant's antennæ, that with one exception, namely antenna No. 8, none of the radiating wires of defendant's antennæ are exactly an integral number of half wave lengths long, and I wish you would please develop for me the comparison between the radiation effected from [fol. 344] an antenna wire of eight wave lengths, which, therefore, is an integral number of half wave lengths, and as compared to that, a pattern radiated from a radiating wire of 7¾ wave lengths, which is not of an even number of half wave lengths, and is substantially the same as antenna No. 2 of the defendant, which is 7.74 wave lengths long.

A. In the case of both of these charts, the radiation pattern is shown for one side of the wire only, and is not shown for the other side of the wire, merely for convenience, because it is the same thing. That is, the lobe shown above the wire—the wire in this case extending in a horizontal direction, would be the same as the lobes below the wire, and would only be a duplication. That is true in the case of both of these charts.

These charts represent a field strength diagram, one of them for a linear wire eight wave lengths long with standing waves and hence, an integral number of half wave lengths long, since there would be 16 half wave lengths in the wire.

The other chart shows a field strength diagram for a wire which is close to the eight wave lengths long in length, departing only one-quarter of a wave length from it. This again shows a field strength diagram from such a wire.

The first thing to notice is that in the case of the eight wave length straight wire, the lobes shown to be connected by a straight line drawn across the figure, that is, if one laid a straight edge across the top of this figure, the lobes should all touch that line.

Q. 453. What does that mean?

A. That means, that the bearing of that is on the amount [fol. 345] of radiation going in these other directions, that is, in the directions of the so-called minor lobes.

Q. 454. Is that wasted radiation?

A. In many cases, it is wasted radiation.

Q. 455. Is it undesirable radiation?

A. It is undesirable radiation practically. That feature, namely, being able to lay a straight edge along all of the lobes so that it will touch them, is not true of the radiation diagram of the seven and three-quarters wave length straight wire; but, on the contrary, there is a decided departure from this so-called straight line rule. The key to this departure is in the dip that I previously pointed out in the radiation resistance curves which occur between each of the integral number of half wave lengths, that is, the valley in this radiation resistance curve that I have produced occurs at a quarter wave length spacing from the nearest half wave length distance.

The significance is this: That the radiation, I am now referring to the radiation of the seven and three quarters wave length straight wire, that the radiation in the undesired direction, that is, in the direction of the minor lobes, is substantially less in proportion compared with the radiation in the desired or maximum direction than it is in the case of the radiation from a wire eight wave lengths long, where these lobes constitute a considerably greater radiated amount of energy in comparison with the long lobe or the principal lobe. The result of this is that better directivity results by departing from an integral number of half wave lengths, and going to an odd number of quarter wave lengths, which will place you in between an integral number of half wave lengths for the length of your radiator.

[fol. 346] It is interesting in a pictorial sort of way why this happens. After all, when standing waves are formed on a linear oscillator, it is merely another way of saying that traveling waves occur simultaneously in two directions, and by virtue of the fact that they travel with the same frequency, that they have the same frequency and travel with the same speed in opposite directions, one has the standing wave. One can consider the radiation pattern from each of the traveling waves taken separately, and when one does so, one finds that there is a radiation pattern somewhat similar to the radiation patterns which one gets using the Abraham formula, with the exception that there occur only two principal lobes or principal lobes generally in the direction in which the wave travels, because that is the way in which you radiate most favorably, and rather a small

amount in other directions, and particularly in the opposite direction nil.

That occurs, if I may use my fingers to represent the principal radiation for the traveling wave going from right to left, these principal lobes will occur so (demonstrating), and going from left to right, will appear so (demonstrating). And the two together give the diagram that we have referred to in connection with Abraham. However, in combining the effects of the two traveling waves, the minor lobes associated with these major lobes add and subtract depending on the phasing and spacing, so that it happens that when the wire is an integral number of half wave lengths long, they add up to produce this pattern which in an integral number of half wave lengths long, and has the straight line characteristic that I mentioned in connection [fol. 347] with the lobes. On the other hand, the manner in which the side lobes add up when it is an odd quarter number of wave lengths long, is such that there is not as good addition of the minor lobes in between the major lobes, and consequently radiation in the undesired direction is thereby reduced.

And this explains also why it is a mistake in this radiation curve to go ahead and assume that because the points calculated in accordance with the Abraham formula used as a basis and which apply to the radiators of an integral number of half wave lengths long, it shows that it is a mistake to assume that a smooth curve drawn through that will also go by interpolation of that curve the radiation resistance of any length of wire having lengths of intermediate values then an integral number of half wave lengths.

Q. 453. Is it or is it not a fact that all the defendant's antenna except antenna No. 8 are electrically substantially a quarter wave length longer than a plurality of half wave lengths?

A. All the defendant's antenna with the exception of No. 8 departs from a length which is an integral number of half waves lengths, and they are, for the most part, very close to an odd quarter of wave lengths in length.

Mr. Darby: I offer in evidence the two charts referred to by the witness, the first, a radiation of eight wave lengths, straight wire.

(Marked Defendant's Exhibit Y in evidence.)

Mr. Darby: Secondly, the radiation of chart 7¾ wave lengths, straight wire.

[fol. 348] (Marked Defendant's Exhibit Z in evidence.)

Mr. Darby: For that purpose, if your Honor pleases, I now offer in evidence the following folder containing:

Bethenod French patent No. 596,737.
Bethenod French patent No. 625,293.
Braun patent No. 763,345.
Brown British patent No. 1449 of 1899.
Heising United States patent No. 1,562,961.
Levy French patent No. 593,570.
Levy French patent addition No. 30,798.

An article by Benjamin S. Melton in the Q. S. T. of August, 1926.

Pages 156 and 157 of a book by John Mills, "Radio Communication, Theory and Methods," published by the McGraw-Hill Publishing Company in 1917.

Reuthe patent No. 1,314,095 of 1919, and
Takagishi Japanese patent No. 70,583, of 1926.

(Marked Defendant's Exhibit AA in evidence.)

Q. 456. Will you refer to the French patent to Bethenod, 596,737, and the translation thereof, and first state what the patent is directed to by its title?

A. This patent to Bethenod is entitled "System of Aerials for the Transmission of Short Wave Wireless Telegraph Signals."

He discloses a short wave directional system, antenna system, consisting of linear conductors, a plurality of half wave lengths long, fed from the opposite poles of a high [fol. 349] frequency generator so that standing waves are produced on the linear conductors.

These linear conductors may be arranged parallel to each other or inclined at an angle to each other, that is, in the form of a V.

In the specification, referring to Fig. 1—and by the specification I mean the translation—on the first page, after describing generally what is shown in the figure pictorially he goes on in the last paragraph on that page to state, "A similar arrangement, that is, as is shown in Fig. 1, may be provided for the emission of short waves and in that case

the antenna thus constituted may be operated at the harmonics." By being operated at the harmonics he means with standing waves such that the electrical length of these parallel wires constitutes a plurality of half wave lengths. That is what is meant by the antenna being operated at its harmonics.

Continuing, "However, in accordance with the arrangement forming the object of the present invention, it is important that the high poles be retained if it is desired that the antenna function in accordance with its fundamental wave. As a matter of fact, calculations and experiments show that with short waves the higher the elevation of the counter-poise above the ground, the greater the advantages that may be derived therefrom. This consideration will lead one to the arrangement shown in Fig. 1 to exemplify the invention." Referring to Fig. 1 of the patent, the two radiators composed of parallel wires are indicated by the numerals 2 and 3 and they are fed from a high frequency source shown by a box labeled HF, the opposite poles of the [fol. 350] source being connected through the wires 5 and 6, one to each of the linear radiators. These radiators, as stated in the passage which I read, are excited at a harmonic, which means that the conductors forming the radiators are electrically long and will consist of a length of a plurality of half wave lengths.

Referring to the last page of the translation of the specification, the first full paragraph on that page, it says, "Obviously numerous other variants are possible, particularly the two networks 2 and 3 of Fig. 1 may be arranged vertically or even inclined not only with respect to the ground but also with respect to one another so as to obtain directional effects either in the horizontal plane or in the vertical plane or in both planes.

"Furthermore, as is well known, the antenna may, in all cases be, if necessary, excited at its harmonics."

The last page which I read refers to Fig. 1 and says that these radiators which are shown parallel to each other in Fig. 1 and extending in a horizontal direction may be arranged still parallel to one another, but extending in a vertical direction, or they may form an angle with each other, in other words, they may form a V. And that being so, and exciting the wires at harmonics, in other words, having a

plurality of half wave lengths, that directional effects in the horizontal plane, in the vertical plane, and even in both planes, may be obtained by using the wires in these various arrangements. It is understood, of course, that proper spacing must be taken into consideration.

[fol. 351] I want to explain that in these groups of wires, in each of the radiators, is shown several wires forming the radiator. I believe Mr. Hogan in referring to the third Carter patent, Fig. 4, for example, where two wires are shown, two wires on each side of the V, that these two wires, although there are two wires shown, that Fig. 4 really represents the equivalent of one single wire V. And also in connection with Fig. 11, where each side of each of the two V's shown there constitutes four wires on a side was said to be equivalent to two single Vs in tandem, that is, one behind the other. Also in connection with the networks, or wires, rather, of Fig. 1 of the Bethenod patent, these may be looked on as equivalent to a single wire radiator in each case. This arrangement, electrically long wires fed from the opposite poles of the high frequency generator, excited in phase opposition, is equivalent to Fig. 3 of the first Lindenblad patent in suit.

Q. 460. Now will you compare the disclosure with the disclosure of the second Lindenblad patent in suit No. 1,927,522?

A. Assuming that the second Lindenblad patent is for a standing wave antenna, in other words, assuming that Fig. 2 represents the second Lindenblad disclosure or invention, then when the networks of Fig. 1 of the Bethenod patent are inclined to each other, the result will be equivalent to Fig. 2 of the second Lindenblad patent.

Q. 461. Now will you compare the disclosure of the Bethenod patent with that of the third Carter patent?

A. In Fig. 1, with the wires inclined to each other, that is equivalent to the third Carter patent in suit.

[fol. 352] Q. 462. With the V antenna?

A. With the V antenna.

Q. 463. Now will you please take up the second Bethenod patent, 625,293 and its translation?

A. This Bethenod patent 625,293 also relates to a short wave directional antenna, and in that case he shows a tilted wire or inclined wire antenna on which standing waves are produced, which, in conjunction with its negative image,

its image in the ground, constitutes a V antenna in which the standing waves produced on the tilted wire are accompanied by standing waves of opposite instantaneous polarity on the image in the ground so as to produce a directional radiation.

And that this angle between the wire and the ground, which forms the bisector of the angle between the wire and its image, may form any angle from zero degrees to 90 degrees.

Referring to the translation of the specification, the first sentence states:

"The object of the present invention is an antenna arrangement which is particularly advantageous in communicating by means of short waves."

The last full sentence on the first page of the translation:

"The portion BC," referring to the only figure, "the portion BC of the antenna may form an angle D of any value from zero to 90 degrees with the horizontal."

And then the first full sentence on the second page of the translation:

[fol. 353] "In order to obtain the greatest radiation efficiency for the antenna, the length of BC should preferably be equal to a whole number of half wave lengths."

Q. 464. How does that recommendation compare with the recommendation of the third Carter patent in suit, prior to the amendment of August, 1934?

A. It is exactly the same recommendation in so many words, that the length of the radiating portion should be equal to a whole number of half wave lengths.

Referring to the figure, it is important to consider the cooperation of the radiating wire BC with its image in the ground. I have already read from the 1901 article of Abraham in which it will be recalled he first considers an antenna located above the earth's surface. Then he stated that the earth's surface will be considered as a perfect reflector for electric waves, and that when so considered, the radiator above the ground is perfectly reflected in the ground and has an image and this image is of the same

length, has the same current distribution and has opposite instantaneous polarity with respect to the portion above the ground.

And then he considered that whole antenna system, that is the wire above the ground and the image in the ground, as one whole unit twice the length of the wire above the ground, with ground removed from all consideration thereafter.

This is typical of the manner in which those skilled in the art analyzed the radiation from an antenna erected above the ground. It is recognized, of course, that actually one never finds a perfect ground. Nevertheless, in consid- [fol. 354] ering antennae in relation to the ground, it has been the custom of those skilled in the art first to assume that it is a perfect ground and whatever resulting radiation occurs, as it does, from an antenna in cooperation with its image in a perfect ground is exactly the same for a distant point as if the two existed in the relation of the reflected image of the real antenna, the reflected image being the negative image, that is, having opposite polarity with respect to the real antenna, and that the radiation at distant points may be determined just as though no ground were present at all, and that the two structures actually existed.

In this patent to Bethenod, this teaching is very clear to one skilled in the art, namely that a radiating wire BC electrically long and with standing waves excited on it, throughout its length, being a plurality of wave lengths long, in radiating, may be considered as being accompanied by another radiator forming the same angle D but on the other side, that is, so far as position is concerned, it is its optical image in the ground, hence a V, and that that image will radiate energy of opposite polarity from the radiator BC, and that the two will combine, just as if two wires were present, two wires of standing waves of opposite polarity and inclined to each other.

Bethenod states that the angle D, that is the angle formed by the wire and its image in the ground, may be from zero degrees to 90 degrees.

Q. 469. Will you please compare the disclosure of the Bethenod patent No. 625,293 with the second Lindenblad patent?

A. Assuming that the second Lindenblad patent is what is shown in Fig. 2, and that it is for a standing wave an-

[fol. 355] tenna system, then when the angle D is some other angle than zero degrees, the antenna system shown by Bethenod, the radiator BC co-operating with the negative image in the ground, will then be equal to Fig. 2 of the Lindenblad patent. In fact, in the second Lindenblad patent on page 2, line 93, it states:

"In connection with Figures 3 and 5, the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground;".

And this means exactly what I have explained in connection with Bethenod and the image of the radiator BC in the ground, in other words, that Lindenblad, after describing the figures 1, 2, 3 and 5 as being excited in phase opposition and having two sides to the circuit, in the passage which I read to you, considers that one side of that circuit is entirely replaced by the image of the remaining in the ground.

And to finish the sentence that I read:

"we will then have two serially connected conductors (conductor 26 and the upper antenna leading to transmission line 24 in figure 3)."

Q. 470. Does that same comparison apply to the third Carter patent?

A. Yes, sir, the same comparison would apply to the third Carter patent.

Q. 471. Will you please refer to Levy French patent of [fol. 356] addition, No. 30,798, and its translation?

A. In Fig. 1 of this patent, to Levy, there is shown an antenna system, consisting of a pair of wires 1 and 2, pair of antenna wires, 1 and 2, excited in phase opposition from a generator 11. And referring to that figure, on the first page of the translation, the second full paragraph:

"In the first place, it is desirable to point out that it is possible instead of adopting the arrangements described in the main patent, to conceive of different variations which may offer advantages in certain cases, particularly where it is desired to radiate energy in a given direction."

That is, this is a short wave directional antenna system,

"For example" (continuing), "wires 1 and 2 in the arrangement shown in Fig. 1 of the main patent, may, instead of being parallel to the same direction, form between themselves any angle and particularly they may be perpendicular. Fig. 1 of the accompanying shows an antenna whose radiators 1 and 2, situated in the same horizontal plane, form between themselves an angle of less than 180 degrees (the same reference numbers have been used as in the main patent to designate corresponding parts)."

In other words, Fig. 1 of this Levy patent calls for a V antenna in which the wires of the V are in a horizontal plane and which are fed from the opposite poles of a high frequency source and therefore in phase opposition.

[fol. 357] Q. 472. Would traveling waves or standing waves form on the radiating antenna wires of this Levy patent?

A. The antenna wires are open ended, therefore, there would be standing waves formed on them of opposite instantaneous polarity, of course, by virtue of the opposite polarity of the feeding.

Q. 473. Will you refer to the original French, that is, Levy patent 593,570, and point out its pertinence?

A. This patent to Levy is of especial interest because he sets forth in the specification much that is of practical benefit in connection with the transmission of short wave signals by the use of horizontally polarized waves. Defendant's antennae are all of this type, that is, horizontally polarized.

Referring to the first sentence at the beginning of page 2 of the translation, it states:

"Further, the invention also contemplates the use of sending antennæ radiating horizontal electric field instead of a vertical electric field, with the purpose of obtaining a great directional effect and smaller losses during propagation.

"An extremely important point, necessitating the use of a horizontal electric field, is that long distance transmission of short waves seems to be effected by reflection on the Heaviside layer."

That is one of the reasons why it is desirable, in fact necessary, in order to communicate at great distances on short

waves to incline the radiation at an angle to the horizontal [fol. 358] in order to make use of the reflection from the ionized strata in the upper atmosphere.

Continuing, the third full paragraph:

"Horizontal antennæ have already been used, but these antennæ have been applied for long wave lengths and relatively very close to the ground. The invention envisages, on the contrary, horizontal antennæ for the transmission of short waves and placed at a height representing an important fraction of the wave length transmitted (one-quarter wave length, for example). Thanks to this height and to the horizontal character of the electric field, the losses in the neighborhood of the electric antenna are greatly reduced."

This instruction as to the range of height at which the antenna should be placed corresponds approximately with what defendant practices. The tabulated data, at any rate, the wires being generally 80 feet above the ground, and the wave lengths of such order that this order of distance of a quarter wave length, or thereabouts, is approximately adhered to.

Continuing at the middle of page 2:

"It is extremely important to raise the horizontal antennæ to a suitable height, greater than one-eighth of the wave length transmitted. In effect, the conductive ground effect is to give an image of the antenna. If the antenna is close to the ground this image, which radiates an inverse field to the one radiated by the antenna, partially neutralizes the effect at a distance from the antenna. This objection- [fol. 359] able feature is avoided when the height of the horizontal antenna is comprised between one-eighth of the wave length lambda and five-eighths lambda. In this case, in effect, the radiations of the image and of the antenna combine. It is easy to figure also the effects of inclination on the horizontal plane of the maximum energy in the vertical plane of maximum radiation, effects which are produced owing to the combination at a distance of and the radiation of the antenna and of its image whose currents are out of phase by a quantity which depends upon the height at which the horizontal antenna is arranged."

The passage which I just finished reading is another explanation, I will put it in different words, of the difference

between the left hand figures and the right hand figures of the Exhibits S and T.

Q. 475. If I may interrupt there, Mr. Kelley, are all of defendant's antennas more than an eighth of a wave length above the ground?

A. Yes, sir, in every case well above an eighth of a wave length.

Q. 477. Will you proceed with the consideration of the Levy patent?

A. On page 4 there is a summary in which various items are summarized with serial numbers. The first item of the summary is the transmission of horizontal electric field waves to favor the reflection without loss on the Heaviside layer and on the ground and the propagation through space.

Item 4A. The single propagation antenna consists of two horizontal wires or two networks connected respectively to [fol. 360] the two poles of a high frequency generator. This item means that the radiating wires are excited in phase opposition.

Reference is also included in here to networks which are of no interest in the reference to the patents in suit, the arrangement shown in Fig. 1 of the patent of addition being the particular one.

4B. The antenna is placed at a height comprised between lambda over 8 and 5 lambda over 8, lambda equalling wave length transmitted, that is, the antenna is placed between an eighth of a wave length above ground and five-eighths of a wave length above ground.

4C. The two poles of the generator are connected respectively to each of the networks, that is, excited in phase opposition.

And 4D. Each of the networks is approximately a quarter wave length long.

And on page 5, 4J, the application of these devices for transmission and reception is envisaged particularly with short waves of less than a thousand meter wave length, that is, that this patent calls for short wave transmission.

Q. 478. Referring to Fig. 1 of this patent where there appear to be three radiating wires, and in the French patent of addition, in Fig. 3, there appear to be three in each of the legs of the V. Is this type of antenna, a number of parallel wires, the same or different from the type shown in the first Bethenod patent that you described with respect

to comparison of Figs. 4, 5 and 11 of the third Carter patent in suit?

A. Yes, sir, these structures labeled 1 and 2 in Fig. 1 of the patent of addition, where three wires are shown stretched along in parallel forming each side of the V, are the equivalent of the single wire V or are the equivalent, [fol. 361] as Mr. Hogan pointed out in connection with the third Carter patent, in connection with Figs. 4, 5 and 11, the equivalent of single wires on a side.

Q. 479. Will you compare the disclosure of these two French patents to Levy, that is, the original and the patent of addition, with the disclosure of the second Lindenblad patent?

A. Again assuming that Fig. 2 of the second Lindenblad patent is for a standing wave antenna, then Fig. 1 of the Levy patent of addition is of course the same thing.

Q. 481. Will you refer to the Brown British patent, 1449, of 1899, and point out its relevancy to any of the three antenna patents?

A. Yes, sir. This Brown patent deals with an antenna system in which the radiating members are linear conductors which are excited in phase opposition with standing waves and are spaced with respect to one another in order to obtain a directional effect.

Referring to page 2 of the specification, the part headed "Complete Specification", the second paragraph, "According to this invention, the transmitting apparatus is provided with two radiating wires coupled one to each terminal of the sparking device and the receiving apparatus is provided with two receiving wires coupled one to each terminal of the coherer."

Q. 482. What is a coherer?

A. A coherer is a detector of high frequency current that was used in the early days of the art—radio frequency.

Mention is made here in the one sentence to both sending and receiving. The same principles, of course, will apply. [fol. 362] The sparking device referred to is in connection with the transmitter and takes the place of the source of oscillations. When we speak of using a generator or a vacuum tube oscillator or what-not, that is the source of high frequency oscillations.

Continuing: "These radiating and receiving wires are respectively placed at a distance apart which has a definite relation to the length of the signaling wires, that of half a length being a convenient distance." And skipping the next sentence, "This placing the wires half a wave length apart causes the system to send its waves or receive them from mainly one direction, which direction would seem to be that of the plane of the wires. If the vertical wires were not so carefully adjusted to the wave length they would transmit or receive the Hertzian waves from any direction."

Referring now to Fig. 1, the radiating wires, the linear conductors are A and A'. The source of oscillations, namely, the sparking device labeled S, excites the wires A and A' in phase opposition, that is, it produces standing waves of the opposite instantaneous polarity on these wires. These wires are electrically short. In being electrically short, that is, not being more than a half wave length, certainly the individual wires would radiate in a direction perpendicular to the wire most favorably; consequently, that is the direction of principal radiation as far as these wires are concerned. Being excited in phase opposition and being spaced as Brown pointed out in the passage that I read, namely, one-half wave length apart, that spacing is the [fol. 363] proper spacing in order to obtain perfect addition in the direction of maximum radiation. And in fact the statement which Brown here makes, namely, that radiation would seem to be, as he puts it, in the plane of the wires, recalls a similar statement made in the first Lindenblad patent in connection with Fig. 3. On page 2 of the first Lindenblad patent, page 2, line 127, referring to Fig. 3: "In a direction normal to the plane of the conductors 14 and 16" (these are the wires of the radiating system) "radiation is cancelled because of the phase opposition of the energy in the conductors, and consequently the hollow cones of radiation indicated in Figure 2 are reduced to four ears or lobes, the axes of which lie in the plane of the conductors."

That is, Lindenblad is here saying that by the arrangement of Fig. 3 the radiation will be confined largely to the plane of the wires, but as I have previously pointed out, it is necessary, in order that this be true, that the wires be properly spaced. This Brown British patent that I am

speaking of truly gives the correct spacing as well as stating that radiation would seem to be in the plane of the wires.

On page 3 of the Brown British patent, line 48, he states:

"The radiating wires aa^1 and also the receiving wires a^2a^3 are respectively placed at a distance apart which has a definite relation to the length of the Hertzian waves generated. This distance may be conveniently half that of the Hertzian wave length, such an arrangement causing the positive radiating wire to supply the positive crest of the wave at the same time as the negative radiating wire sup- [fol. 364] plies the negative crest of the wave and the waves to be thus transmitted or received mainly in the direction of the plane of the radiating and receiving wires."

He describes here in words again what I showed in one of the exhibits where I said you could trace the side waves with your fingers without having to change the distance between them when addition was in phase, that is, perfect addition; otherwise it would be impossible to maintain a constant distance between the fingers in tracing the two waves. And I also pointed out that the reason they came into phase was the difference in path, the distance that they had to be traveled. That is what Brown means here when he speaks of the positive crest of the wave radiating at the same time as the negative radiating wire supplies the negative crest of the wave so that they will then come together.

Q. 487. Now, what would have to be the necessary relation of the wires of the antennæ in order that radiant action would occur in a direction making the same angle with each conductor?

A. The wires in that case would have to be parallel.

Q. 488. Would that language that I read to you correctly or incorrectly describe the antennas employed by the defendant?

A. That language would incorrectly describe the antennas employed by defendant.

Q. 489. Will you please turn to the Takagishi Japanese patent 70,583 of 1926, and point out its pertinency from the translation and the drawings to the subject matter here in issue?

A. As far as the drawings are concerned, I am afraid I will have to adopt my own system of numbering, since I cannot read Japanese.

[fol. 365] Q. 490. All right, do so. Might I suggest that you use the system adopted by the translator, because the translations have been agreed upon?

A. This patent of Takagishi relates to a short wave directional antenna system in general, and in particular to an antenna system composed of linear conductors a plurality of half wave lengths long excited in phase opposition, that is, with standing waves of opposite instantaneous polarity. This is indicated in what I shall refer to as Fig. 1, the upper right hand figure on the first page of the figures. Here two wires a and a′ are shown, the designation a and a′ being at the upper ends of the wires. The straight line extending from these crosses are the wires. The curved lines shown on there represent current distribution, and are drawn so that they indicate an opposite polarity distribution from the wire a′, that is, the one on wire a is opposite that of a′.

The next figure to the left shows a generator feeding the wires shown in a circle with a little sine wave symbol in the circle.

The figure immediately below the last mentioned figure, which I believe is Fig. 4, shows a second pair of linear oscillators arranged in the same plane as the first pair in order to obtain a reinforcement of the radiation from the first pair. It appears that in this patent to Takagishi his instructions as to spacing are not all that one might desire, but in that respect they are just as good as those given in Fig. 3 of the first Lindenblad patent, Takagishi starting out with two electrically long wires excited in phase opposition and collaterally spaced.

He wanted to do more than that, he wanted to control [fol. 366] the angle of radiation, that is, the angle with the horizontal, by adjusting his second wire, that is, he wanted to do something in addition to merely placing the two wires in parallel. But as far as his showing the starting point, two wires excited in phase opposition which are electrically long and parallel and collaterally spaced, the information contained here is just as good as that contained in Fig. 3 of the first Lindenblad patent.

Q. 492. What does Takagishi do with his wires, does he offset them at an angle with respect to each other, referring to the drawing which you called Fig. 1?

A. Yes, sir, he offsets them at an angle with respect to one another in order to obtain his control of direction that I mentioned.

Q. 493. How does that angle compare with the angle shown in Fig. 4 of the Lindenblad patent, No. 1,884,006, and designated by the reference symbol alpha? Is that the same angle?

A. No, sir, it is not. He varies it and it may have any number of values. He describes an experiment in here in which he does try several values.

Q. 494. Several values for the angle theta?

A. He calls it the angle theta.

Q. 495. Is it or is it not the angle of offset between the wires in exactly the same sense as the angle alpha is employed in Fig. 4 of the first Lindenblad patent?

A. It is the angle of offset of the ends of the wires.

Q. 496. Now, will you please proceed with the translation, pointing out the passages thereof which are pertinent?

A. On page 2 of the translation, the first sentence:

"The purpose of the invention is to furnish a directional [fol. 367] antenna by which a desired result can be readily obtained at will when most of the energy of the electric waves is radiated in wireless telegraphy and wireless telephony at a given altitude above the ground, or in receiving the electric wave traveling through the air at a given angle. Furthermore, this invention makes possible efficient communication by adjusting the radiation angle depending on the distance between the transmitting and receiving stations and depending also on the seasonal and atmospheric conditions. This applies particularly to short electric waves which are noted for their properties of reflection and refraction functions."

In other words, this patent is directed to the short wave antenna system.

Then on page 3, the last sentence in the first paragraph, or, rather, the second sentence in the first paragraph:

"It has been theoretically proved that when, as has been known in the past, a vertical antenna of a comparatively short wave length is employed for transmission, the energy

of the electric waves is greatest in a horizontal direction. On the other hand, when the antenna is replaced by an antenna which has a large natural wave length, the direction of the radiation of maximum energy of the electric wave is to some extent inclined to the horizontal."

What he means to say there is, of course, antenna which is electrically long, rather than an antenna which is elec- [fol. 368] trically short, and there follows, near the bottom of the page a table indicating what he means, that the angle to the horizontal, that is, the angle to the perpendicular to the wire is given in the second column for the number of harmonics, that is, the number of half wave lengths or quarter wave lengths in this case, since it is grounded, corresponding to different lengths of wire, that is the number of harmonics would be three-fourths, four-fourths or one, and for 15 it would be three and three-fourths wave lengths long.

He stated on page 7 of the translation in the first full paragraph:

"What this inventor desires to secure by this patent are points other than those already known."

I mentioned that in addition to using the wires in parallel, he wants to obtain, in addition to that, the control of the angle of radiation over and above that.

Q. 498. I call your attention to the statement on page 4 of the translation beginning with the words "in accordance with this invention".

A. Oh, yes, about the middle of page 4:

"In accordance with this invention, the bulk of the radiated energy is directed at some angle to the horizontal plane. This is controlled by proper positioning and phasing of the two vertical antennæ instead of primarily choosing the order of the harmonics has been done heretofore."

Q. 499. What does that mean?

A. That means, the proper phasing, being phase opposi- [fol. 369] tion in this case; and proper positioning meaning the proper spacing apart of the wires.

Q. 500. Will you now refer to the Heising patent, 1,562,-961, and particularly Fig. 10 thereof, for its bearing on this question?

A. This patent to Heising also refers to a directive antenna system consisting of parallel antenna wires, a plurality of wave lengths long. He mentions in the specification a length of 12 wave lengths long, extending on one side only of the source. The wires are spaced laterally, that is, apart, and longitudinally, that is, staggered, and properly phased in such a way that one pair of principal lobes of radiation is cancelled, whereas the other pair of principal lobes of radiation is strengthened.

That is diagrammatically illustrated in Fig. 10. In Fig. 10 the wires are 20 and 21. The wires are staggered as to their ends as shown, and are spaced collaterally as described in the specification. Referring to page 4, line 122, he states, referring to Fig. 10:

"As is diagrammatically indicated in Fig. 5, there is directive radiation in two lateral directions. An arrangement of multiple antenna for suppressing radiation in one of these directions is illustrated in Fig. 10, in which parallel directive antennæ 20 and 21 are shown spaced with their respective energy transmission loops 22 and 23 from the terminals 24 and 25 connected with the source extending in the same direction and neutralized in space. If energy of the same phase is simultaneously supplied at points 24 and 25, and if these points are a half a wave length apart in one direction in which their respective antenna radiated [fol. 370] most powerfully, the effect of the energy radiated from the point 25 will be to oppose and neutralize that radiated from point 24 in this direction."

This is for the reason that for all points in space in this direction, these radiated energies will be opposite in phase, in other words, loop 22 will neutralize loop 23.

If the distance between the points 24 and 25 does not correspond to a half wave length, the phase of the energy supplied to one of the antenna may be so shifted by a variable impedance device 30 that the points 24 and 25 will tend to radiate energy which will neutralize in space in the direction of loops 22 and 23. This will leave only the loops 26 which are similarly directive and which are additive.

In connection with the loops, as Heising calls them, and we have referred to them as lobes of radiation, Fig. 8 of this Heising patent shows diagrammatically what these

lobes mean. The antenna in Fig. 8 is shown by the horizontal line to the left ending in an arrow head, the direction only being significant.

This patent relates to traveling wave antennæ. That is the reason why we have two major loops or lobes of radiation, rather than four major lobes of radiation.

What Heising does then in the arrangement shown in Fig. 10 is equivalent to what was intended to be accomplished by Fig. 4 of the first Lindenblad patent.

Heising shows correctly how this is to be accomplished. The loops 22 and 23 are shown radiating from correspond- [fol. 371] ing points on the two wires. It so happens that the stagger of these wires is about 45 degrees. And it also so happens that a line drawn from 25 to 24 would be parallel with the ends of the wires, and would also be in the line of the lobe of radiation.

That the distance between the points 25 and 24 is arranged to be worked to an odd number of half wave lengths, and consequently at a distinct point such radiation in this direction would be cancelled.

On the other hand, radiation from 24 and 25, extending in the directions 26, since the starting points in that direction are the same, there will be perfect addition of the loops in that direction.

When this is accomplished, it results in a unidirectional characteristic without the addition of a second similar pair of wires for the simple reason that the units composing a combination of Fig. 10 are themselves traveling waves, and they will therefore not be any oppositely directed lobes, but the lobes inclined to each other as shown in Fig. 10.

Consequently, it is not necessary to add as was intended in Fig. 5 of the first Lindenblad patent, a second similar pair of wires in order to remove one of the bidirectional lobes of radiation and confine the radiation in one direction.

Q. 503. Now, referring to Fig. 8 of this Heising patent, I find again an angle designated by theta, extending between the direction of radiation of the lobe and the antenna. Is it or is it not the same angle alpha or theta of the third Carter patent?

A. No, sir, it is not the same, because in this case it designates an angle of principal radiation from a traveling wave [fol. 372] antenna in which phasing devices have been added to reinforce—approximately speaking—to reinforce the

lobe in some other direction than the lobe which is nearest the wire.

The designation of this as an angle, that is merely to designate it as an angle of principal radiation, or the angle which Heising intends to use.

Q. 504. Now, will you please refer to the specification in this Heising patent, page 1, line 91, and explain what is meant by that?

A. At page 1, line 91, it states:

"The invention permits radiation in one lateral direction to the substantial exclusion of radiation in any other by an arrangement of parallel antennae."

That is what I have been describing in connection with Fig. 10.

He means by that to eliminate one of the sets of lobes and to arrange for the perfect addition of the other sets of lobes.

Q. 506. I come to the sentence at line 5, page 2, which states:

"The antenna may also be curved laterally to add to the focusing effect."

Now, what bearing, if any, has that upon Fig. 1 of the second Lindenblad patent? Does that or does that not suggest a laterally curved antenna, such as Fig. 1 of the second Lindenblad patent?

A. No, sir, because in this case, in addition to the curve, there is a change in the loading used on the antenna and the [fol. 373] focusing effect here, as I understand it, is for a nearby point, a comparatively nearby point.

Q. 507. Will you now refer to the article by Melton in the Q. S. T. book?

A. In this Melton article in Q. S. T. of August, 1926, there is shown in Figure 1, diagrammatically, a whole series of linear radiators of differing electrical lengths.

They are shown for every quarter wave length, from one-quarter wave length to eleven quarter wave lengths, in other words, all the way from a ground antenna, at its fundamental, one-quarter wave length, to an electrically long linear conductor, with standing waves throughout its length. These are shown, as indicated in Figure 1 as 10 meter radiat-

ing systems. In other words, short wave radiating systems.

In the heavy printing under the figure, the last paragraph in that heavy printing, states:

"While the antennas shown are vertical it is possible to operate the ungrounded ones in any position; both the grounded and ungrounded ones may be bent instead of straight."

What he means by bending them is taking the very long vertical antenna, to bend it over horizontal, and consisting of wires which are electrically long, and co-operate with its image in the ground. As I have pointed out in connection with other references this image will be excited automatically in phase opposition, and then becomes equivalent to Fig. 3 of the first Lindenblad patent.

Q. 509. Will you next point out the significance of pages 156 and 157 of the Mills book?

[fol. 374] A. In this book by Mills, entitled, "Radio Communication, Theory and Methods," he gives on the pages indicated general formulae applicable to determining the directional effects of any antenna. These formulae are given on page 156 and he shows in particular one use, namely that of determining spacing and phasing in order to eliminate radiation in one particular direction, and also what the radiation will be in other directions; and the conclusions on page 157, the end of that section, that is, the end of the first full paragraph:

"This general method may be applied to determining the directive effect of any combination of antennae."

That is used in a general way, the principles involved in these formulae may be applied generally. In other words, all of these problems connected with directional transmission, concern two things, spacing and phasing.

Q. 510. Will you compare very briefly the disclosure of this Mills book insofar as it is directed to reflector action with the disclosure of the first Lindenblad patent and the third Carter patent in suit?

A. Well, referring on page 156 of Mills to the formulae below the figures, he states—let me read first the sentence beginning just above the figures:

"Let the phase theta and the distance d be so chosen that at P sub 1, the effects of the two antennae neutralize."

Referring to Fig. 113, P sub 1 is taken on a line with the two antennas A sub 1 and A sub 2.

Continuing: "Then a difference in phase of pi must exist between the two effects."

[fol. 375] In other words, they must be in opposition 180 degrees apart.

Then he sets down his equation which represents this condition mathematically, and the next two equations merely show explicitly in terms of theta the difference in phase between the two antennas A sub 1 and A sub 2. Taking the last expression where theta equals pi plus or minus 2 pi d divided by lambda, it is seen that whenever d is one-quarter of a wave length, that is lambda over 4, or for that matter, any odd multiple of quarter wave lengths, theta will be equal to plus or minus pi over 2, which in radians is the same thing as plus or minus 90 degrees, which is referred to generally in the literature as phase quadrature. And that represents the condition where there will be cancellation in one of the two opposite directions and addition in the other of these two opposite directions.

Q. 522. With reference to the second Lindenblad patent in suit, No. 1,927,522, Mr. Hogan has adv nced as the advantages of this patent, and I am reading from the answer to Q. 66 (R. p. 174):

"The principal advantages of this Lindenblad diverging long wire antenna are its simplicity, its cheapness, its operativeness over a considerable range of frequencies, and its ease of erection, maintenance and adjustment."

Are there any instances in the prior art to which you have referred where those advantages are all obtained?

A. Those advantages would be obtained in b o t h Bethenod's and also in Levy.

Q. 523. Finally in reference to the alleged advantages of [fol. 376] the third Carter patent, as given by Mr. Hogan, in answer to Q. 81 (R. p. 189), they are, "First, the exceptionally high directivity per unit of the antenna system." What instances of the prior art, if any, would give that same advantage, and in this connection, Mr. Kelley, you may include in the prior art the first two Lindenblad patents?

A. The first Lindenblad patent certainly if arranged as it was intended to be arranged so as to obtain the intended object, would be fully as directive as the third Carter patent.

Q. 524. And the second point of advantage is "its low cost

of erection and maintenance." What instances of the prior art can you there refer to?

A. It would amount in the case of comparing the first Lindenblad patent with the third Carter patent, of a few poles difference in favor of the third Carter patent.

Q. 525. How about the comparison of the second Lindenblad patent to the third Carter patent?

A. In comparing the second Lindenblad patent to the third Carter patent there should be no difference at all.

Q. 526. The third point is its simplicity and stability of adjustment. Is or is not that advantage obtainable in the prior art, referring to the first and second Lindenblad patents?

A. That advantage is obtained when the first Lindenblad patent would be arranged to accomplish the intended object and of course the second Lindenblad patent likewise.

Q. 527. The fourth point is the fact that it utilizes standing waves effectively and there is no need to minimize them either by having exceptionally great length or by using [fol. 377] terminal resistors. Is that advantage obtainable in either of the prior Lindenblad patents?

A. Yes, sir, it is obtainable specifically in the first Lindenblad patent which is for a standing wave antenna.

Q. 528. If the second Lindenblad patent discloses a standing wave in its Fig. 2, then——

A. If the second Lindenblad patent is to be understood to disclose a standing wave antenna system, then the same advantage applies there.

Q. 529. Now, the fifth point of advantage is its adaptability to successful use with a wide range of lengths of wires and lengths of wave. If that is an advantage of the third Carter patent is it likewise an advantage in any reference to the prior art to which you have referred?

A. It is equally true of the first and second Lindenblad patents.

Q. 530. The sixth advantage is its high radiation efficiency?

A. Well, that would be equally true of the first two Lindenblad patents.

Q. 531. The seventh advantage is that if the side wires are longer than about six wave lengths in length it has relatively high directive efficiency for a considerable range of wave lengths in any one structure?

A. That is true also of the first two Lindenblad patents.

Q. 542. Now, in answer to X Q. 819 (R. p. 282), Mr. Hogan

testified: "There are no statements in the second Lindenblad patent as to angle"—and Mr. Hogan testified in answer to X Q. 822 (R. p. 283), where he was asked: "What do you mean by a gradually diverging V?

A. I think there is no numerical limit to such a word as 'gradually' but for practical purposes, I would expect the angle to be of the order of 45 degrees or less, certainly less [fol. 378] than 90 degrees." And in that connection it is noted that Defendant's Exhibit G shows an angle of 122 degrees. Have you had worked out wave patterns illustrating exactly the same results in so far as direction of predominant radiation is concerned with an angle less than 45 degrees?

A. Yes, I have. In this case there is an angle of 40.8 degrees, and the wires are 16 wave lengths long, the radiation in the direction of the axis of the conductor system is approximately zero, this being an angle which is within the 45-degree angle.

Q. 543. And in what direction would the radiation be predominant?

A. Predominant radiation will be in a direction other than the bisector or the axis of the conductor system, in substantially different directions, they would not be confined all in one direction.

Mr. Darby: I offer the chart produced by the witness in evidence.

(Marked Defendant's Exhibit BB in evidence.)

Q. 544. In cross-examination Mr. Hogan stated at X Q. 819 (R. p. 282), in answer to this question: "Does the patent, if there is a possibility even that that general statement is not true, does the patent tell you what is the limit of angle between the legs of the V, where it will obtain the results of the patent or where it will not do so?" referring to the second Lindenblad patent. The answer is: "There are no statements in the second Lindenblad patent as to angle whatever and no numerical limits given. There are given a set of recommended cases, wherein the wires are five to ten wave [fol. 379] lengths long, and the spacing is about one-fifth the length of the wire."

Have you had radiation patterns made to illustrate where, under the conditions given by Mr. Hogan, the major or predominant radiation would be obtained?

A. I have.

Q. 545. Will you please produce them and point out where it would be obtained under the conditions given by Mr. Hogan, and in what respect, if any, they conform with the teaching of the patent?

A. There are two radiation patterns, one of which is for a length of the sides of a V of four wave lengths, and the other is for a length of eight wave lengths.

Referring first of all to the V which has a length of four wave lengths, there is plotted here the radiation diagram which would be obtained with the spacing at the open end one-fifth of the length of the wires, as Mr. Hogan pointed out. The wires are shown in the figure extending to the right of the center, they are not very distinct, coming out pretty near to the valley of the small lobe that is right near the No. 2. Those two lines inclined to each other show the direction in which the wires of the side of the V extend. The axis of the antenna system of course is the line right through the middle from zero to zero degrees.

With this V, there is a space at the outer end one-fifth of the length of the wires and with each side of the V four wave lengths long, it can be seen that not only does predominant radiation not take place along the axis of the conductor system, but the predominant radiation is in the directions which lie wholly outside of the wires forming the system.

[fol. 380] And referring to the radiation pattern, V antenna, where the sides are eight wave lengths long and the opening is again, in accordance with Mr. Hogan's specification, that is, one-fifth of the length of the wires, it is seen in this case the wires being drawn in similar to the other diagram, that radiation is not only not predominant along the axis of the system, but also that it is predominant in directions outside of the wires forming the system. In other words, these two diagrams taken together cover the range of from four to eight wave lengths on a side and show the same effect, the difference between the two, that is, if one went gradually from one to the other, there would be gradation from one to the other.

Mr. Darby: I offer in evidence the chart produced by the witness with reference to the four wave length antenna.

(Marked Defendant's Exhibit CC in evidence.)

Mr. Darby: I offer in evidence the chart produced by the witness marked eight wave lengths antenna.

(Marked Defendant's Exhibit DD in evidence.)

Cross-examination.

By Mr. Blackmar:

X Q. 546. Mr. Kelley, in your direct examination, you told us your experience and qualifications with respect to cable, telephone, telegraph and carrier currents. I would like to get an idea of what your practical experience in radio has been.

A. Well, as you recall, I stated that my training had been in radio engineering, and all during my professional experi- [fol. 381] ence, I have been applying radio engineering principles to my work, and I have had some experimentation, that is, some work with my own hands, with radio. But if I may answer your question fully, Mr. Blackmar, I would like to relate briefly something of my own experience in connection with what I have to say.

I have done many jobs—engineering jobs of which I had never seen any of the equipment or apparatus either during the process of manufacture or installation, which I designed and kept in touch with by correspondence, and had satisfactory reports of successful operation, so that as far as I am concerned, it is not always necessary that I handle these things with my own hands.

I have had much experience of that nature, and you must appreciate that engineering principles are not things applied to a very limited range of application but are of very wide application.

So far as these patents in suit are concerned, I am familiar with the theory, and they are largely theoretical, as you will probably appreciate, and as far as impedance matching transmission lines, and so forth, are concerned, I have had years of experience with that, and these distinctions as to frequency, which I think is implied in your question, are wholly unwarranted from the standpoint of engineering.

The engineer wants to know frequency, to be sure, but when he knows frequency, he knows what to do. In certain cases I know that he will find that he can make certain approximations which are readily available from the formulas that are employed, and so forth.

All I wanted to point out is that so far as climbing poles and making adjustments and conducting, you might say,

[fol. 382] radio transmission development of apparatus, I must admit that I have not had that sort of training.

X Q. 547. How about making measurements in the field?

A. I have made measurements experimentally. It has not been my job to go out and make them.

X Q. 548. When has been your first experience with respect to directive antenna design and construction?

A. As I told you, I have not actually done that sort of work. I have followed the art, and I know and understand and can explain what it all means.

The principles involved are of general applicability.

X Q. 990. When you said certain angles were used to intentionally secure certain results, you did not then mean the antennas were set up with those angles with those results in mind?

A. I cannot testify to that of my own knowledge.

X Q. 991. You testify as to what occurs in the antennæ after they are built, that is your testimony?

A. I am speaking of it functionally, and I use the word "intentionally" merely to indicate that that was the function.

X Q. 1061. Will you please refer to Q. 401 (R. p. 322), sentence beginning, where you were discussing, I think, defendant's antenna No. 2; you stated:

"And it is seen by comparing the two right hand figures that instead of sacrificing any real radiation by virtue of using a different angle, a different angle is used deliberately in order to gain more radiation in the direction in which it actually goes out."

[fol. 383] Now, from what you have already stated, I assume that you do not intend that to mean that you know the angle was chosen deliberately for that purpose when the antenna was set up, is that correct?

A. Clearly you know the knowledge that I possess in that respect from my previous testimony.

X Q. 1062. In other words, you are merely testifying to results?

A. The functioning.

X Q. 1063. What the functions are and what the result would be, as I understand it?

A. That is correct.

X Q. 1064. Similarly on the preceding page, you state that defendant is not relying on that theoretical radiation, and the same thing is true of that, as I understand it?

A. Yes, of course.

X Q. 1065. Again in answer to Q. 403 (R. p. 323), about the sixth line from the end of the paragraph:

"by an apparent sacrifice in the theoretical radiation defendant departs from the teaching."

That, again, as I understand it, is merely your conclusion as to the effect of the structure as it exists?

A. As it exists, yes, sir.

X Q. 1066. I am asking you each one of these, Mr. Kelley, so there won't be any misunderstanding later on.

A. Yes, sir.

X Q. 1067. Or I trust there won't. Again on page 309, Q. 356, you state: "In defendant's structure, it"—meaning the angle—"is 45 degrees. The reason for this being that by using this angle different from the Carter," certain effects are obtained. Again, you don't mean to suggest that [fol. 384] you know why any particular angle was chosen, or do you mean so to suggest?

A. I don't mean so to suggest. This is all as to the functioning. As I have already said before, I have no knowledge of when they were designed, who did it, or what they did. I have only seen them as they exist.

X Q. 1068. Or why they were designed in certain ways or what they hoped to accomplish with them outside of possibly directivity or something of that kind?

A. Yes, only as they exist.

X Q. 1069. With respect to defendant's Exhibit S and T, will you please first state on the record whether these are intended to represent relative power or relative amplitude?

A. Relative power, sir.

X Q. 1070. And in the four right hand diagrams, there is, as I understand it, assumed to be some kind of earth over which the antenna is erected?

A. It is assumed to be perfect earth—perfect ground, but if you care to see them, we have it for very poor ground and they will show the very same general state of affairs, if you wish to have me produce them.

X Q. 1071. From that, as I understand it, these diagrams are calculated, are they not?

A. Yes, sir, they have been calculated.

X Q. 1072. They do not represent any actual measurements of antenna field strength or power or anything of the kind?

A. No, sir, they don't represent actual measurements. They were calculated.

X Q. 1073. So that the statement at the top over the right hand figures in each case, "What it actually is," is not intended——

A. Is not——

X Q. (Continued.) —is not intended to indicate that that [fol. 385] was based on actual measurement?

A. No, it is not intended to indicate other than that it was calculated.

X Q. 1074. That means "what it actually is" in your opinion or in the opinion of the person who made these calculations, is that correct?

A. That is correct, sir.

X Q. 1075. And I assume you did not make the calculations?

A. No, sir, I had them made.

I would like to correct an answer that I made right at the close of last night, or yesterday's session, an answer that I made without sufficient reflection. I am referring to X Q. 1074, which reads:

"That means"—referring to Defendant's Exhibits S and T—"That means what it actually is in your opinion or in the opinion of the person who made these calculations, is that correct? A. That is correct, sir."

I did not wish to imply by this answer that mathematical calculations are a matter of opinion; were it not for the use of mathematical calculations, engineers would be helpless, and to cite one example, in the building of the Hol and Tunnel, where the computations which preceded this work enabled the engineers to meet in the middle of the river with very few inches to spare; and I do not believe I need to laborate any further than that, namely that mathematical processes and calculations form the substantial assistance to the engineer without which he would be helpless; and also that such calculations are, of course, subject to checking. It is possible for one to make a mistake. It is also possible for one to discover a mistake or for somebody else to check these calculations.

[fol. 386] X Q. 1078. I was about to ask you that: Calculations are not always correct?

A. That is correct. They are subject to checking, using well-known mathematical principles.

The Court: What you really meant was that the calculations formed the basis on which you formed the opinion?

The Witness: You could put it that way, your Honor.

The Court: That is what you meant?

The Witness: Yes, your Honor.

X Q. 1079. You spoke of the Holland Tunnel. Do you remember an incident in connection with the bridge being built across the St. Lawrence River at Quebec?

A. Well, my only reply to that is: "To err is human," and applying mathematical principles wrongly, of course, leads to wrong results, and that, of course, is subject to checking, and any of these calculations that we have produced, we are only too glad to have your expert and your engineers go over them and point out wherein they agree or disagree, so that there be no conflict in that respect.

X Q. 1080. In order that my question may be understood, does your recollection check with mine, that there was a cantilever bridge to be built across the St. Lawrence River near Quebec which collapsed prior to its completion, I think, twice?

A. As I recollect, they had considerable trouble with that bridge, and it did collapse.

X Q. 1081. And another thing that is necessary in arriving at a correct mathematical result is to make correct assumptions in the first place?

A. Oh, yes, that is always true.

[fol. 387] X Q. 1082. And in addition to that, mathematics, when applied to practical situations, do not always come out in accordance with expectations, possibly because there are factors that may be overlooked or that are not understood, is that correct?

A. Well, in a general way it is correct, but actually engineers have been pretty successful in predicting their results, and I have had some experience in that line myself.

X Q. 1083. Was Steinmetz a recognized mathematician?

A. Steinmetz was recognized to be a leader in his art.

X Q. 1084. How about John R. Carson of the Telephone Company?

A. Yes, sir, John R. Carson, to the best of my knowledge, is considered to be a very fine mathematician.

X Q. 1085. Are you familiar with the fact that they did not agree as to certain developments on the question of wave propagation along parallel wires?

A. It is quite possible they did not agree, and I am sure they could find the point of disagreement and check each other's calculations.

X Q. 1087. Will you please refer to Questions 292, 293 and 294 (R. p. 296). Q. 292 is: "Referring to defendant's antenna, in the case of any antenna employed by defendant, is the propagation of the radiant energy predominantly in the plane of the wires?

A. No, sir, the radiation is sent out at a considerable angle, a substantial angle, to the plane of the wires.

"Q. Is that accomplished accidentally or as a matter of design?

"A. That is accomplished as a matter of design.

"Q. For a particular purpose?

"A. Yes, for the——"

[fol. 388] Then the answer was interrupted.

Again, in view of what you said yesterday, I understand that you would not want that answer taken to mean that you know the purpose of the design of these antennas at the time that they were erected?

A. No, sir, inasmuch as I did not participate in the design of these antennas.

X Q. 1088. And what is stated there is your opinion as to the actual action of the antennas after they had been set up, is that correct?

A. That is correct, yes, sir.

X Q. 1089. How were these antennas designed (using "design" in that sense) to accomplish this result, namely, radiation at an angle from the plane of the wires?

A. As I explained in my direct testimony this result is accomplished by erecting the antenna with the wires parallel to the surface of the earth, and having such an angle between the wires that the radiation which is sent out by the wires, in conjunction with the negative image of the antenna system in the earth, will radiate better at an angle to the horizontal than in any other direction, the angle being

desirable because of the nature of the transmission requirements for short waves through space.

X Q. 1090. In the absence of ground effects what direction with respect to the plane of the wires would the predominant radiation have been in?

A. Without the ground effect, you mean an antenna——

X Q. 1091. In free space?

A. In free space, in other words, a theoretical consideration, then it would be in the plane of the wires, substantially in that direction.

[fol. 389] The Court: Instead of shooting straight you want to take advantage of the trajectory, is that the idea?

The Witness: Yes, sir, that is the idea.

X Q. 1092. But it is the ground effect that causes that result?

A. It is the co-operation between the antenna and the ground that accomplishes that result, yes, sir.

X Q. 1093. And referring to Defendant's Exhibits S and T, the left hand diagrams indicate, I believe, what you have just stated, that is, in free space the antenna would radiate in the plane of the wires predominantly?

A. That is correct, sir.

X Q. 1094. How could you build a horizontal antenna and avoid this ground effect?

A. Well, you might build one on an airplane, a rather unusual thing to do. I do not mean that to be taken literally, because airplanes do have antennas. But, as you can readily see, it would have to be removed from the ground.

X Q. 1095. In other words, in practical cases with respect to antennas in fixed locations, the ground effect always enters into the radiation pattern, always affects the radiation pattern, does it not?

A. It must if the antenna is constructed on the ground.

X Q. 1096. By "on the ground" you mean to include 80 feet above the ground?

A. Yes, sir, of course.

X Q. 1097. Do you know what the character of the ground at Sayville is?

A. I am not familiar with it in detail, but I understand it is not of the best characteristics. I cannot give you the details, but I can obtain them for you if you wish.

[fol. 390] X Q. 1098. Is it perfect ground?

A. No, there is no perfect ground.

X Q. 1099. That is a mathematical assumption?

A. It is an assumption that is usually made by engineers, certainly in making the first calculations in respect to what they expect to get in the way of radiation from a given antenna.

X Q. 1100. Then the actual character of the ground, since you say it is not in practical cases perfect, modifies those conclusions to a greater or less extent, doesn't it?

A. It modifies the conclusions in certain respects and in other respects, relative values may remain pretty much the same.

X Q. 1101. But in some ways it does alter the conclusions?

A. In some ways it does alter the conclusions, yes, sir.

X Q. 1102. Then I take it from your prior answer you cannot tell me in general the conductivity or dielectric constant of the ground at Sayville, is that right?

A. I cannot tell you offhand, but I can obtain that information for you if you wish it.

X Q. 1103. Will you be prepared to give it to me after the noon hour?

A. I will try to. I am not absolutely sure that it is available, but if it is I will do so.

X Q. 1104. I think it is already on the record, but will you state again as to the left hand diagrams of Defendant's Exhibits S and T, whether or not in those cases the ground effect is neglected?

A. You are holding two diagrams. In the left hand figures the ground is entirely neglected.

The Court: In laying out these systems do you do it without regard to the ground and then alter it to change the [fol. 391] situation as the ground may require, or do you attempt to anticipate the effect of the ground?

The Witness: The effect of the ground, your Honor, is anticipated in so far as it can be practically. Ground conditions vary even in the same location, but in general one can obtain a fair picture of what the result will be.

The Court: And then you make the modifications that may be necessary by reason of any change in those conditions,—practically?

The Witness: Yes.

The Court: You anticipate?

The Witness: Yes.

The Court: But if your anticipations are not completely realized then you modify your systems to meet the conditions, practically?

The Witness: That could be done.

The Court: Is it done or are they always so exact that they strike it right?

The Witness: Your Honor, the matter has been so thoroughly analyzed in the art that a pretty good guess can be made at the outset.

X Q. 1105. A good enough guess ordinarily?

A. A good enough guess ordinarily, yes, sir.

X Q. 1106. Will you please refer to the third Carter patent in suit and look at Fig. 7; in general do you not understand that that shows substantially the same with respect to the operation of a V antenna as is shown in the left hand figures of Defendant's Exhibits S and T?

A. In the vertical plane, yes, sir.

X Q. 1109. That is what it states?

A. Yes, sir.

X Q. 1110. And it also states, does it not, "Ground effect neglected"?

[fol. 392] A. It so states, "Ground effect neglected," but if I may I would like to also refer to Fig. 6, which is in the horizontal plane.

With respect to that figure, no such modifying title is given and consequently one must assume that Carter has in mind that some effect due to ground would happen in the case of Fig. 7, but not in the case of Fig. 6, which shows it in the other plane.

X Q. 1111. Now, you have stated, I think twice, on the record that the defendant uses only V antennas. Am I to understand that you intended to imply that it uses no other types of antennas at its Sayville station than V antennas?

A. I was referring always to the antennas in the stipulation.

X Q. 1112. So far as you know, there may be, or you do know that there are, other types of antennas used there?

A. I believe there are other types of antennas used there, but I am not familiar with what they are—I cannot give you a list of them.

X Q. 1113. Now, if one of the defendant's V antennas, such, for example, as antenna No. 1 or antenna No. 5, were

in free space, would the radiation be predominantly along the line of the bisector of the angle of the V?

A. Numbers 1 and 5?

X Q. 1114. For example, numbers 1 and 5, yes.

A. Yes, sir, I believe it would.

X Q. 1115. And is that also true with respect to the other of Defendant's V antennas which are covered in Plaintiff's Exhibits 7 to 13, inclusive, that is, all of the V antennas?

A. Yes, that is substantially true.

X Q. 1116. You state that as these antennas are set up, the radiation is sent out at a considerable angle, a substan- [fol. 393] tial angle to the plane of the wires. That appears in answer to Q. 292 (R. p. 297). Can you state what this angle is?

A. It is shown on Exhibits S and T.

X Q. 1117. Is it the same for all antennas, you mean?

A. Not necessarily the same for all the antennas.

X Q. 1118. As a matter of fact, it is not the same for the two shown on Defendant's Exhibits S and T, is it?

A. No, sir, it is not.

X Q. 1119. Do you know what the angle is with respect to all of the antennas?

A. No, I couldn't say. That would have to be determined in the same way.

X Q. 1120. How would you determine it?

A. By applying the calculations well known in the art, assuming a ground which is poor enough to include the worst ground one would encounter in a given location, and to compute the resulting effect between the antenna system above the ground in cooperation with its image in the ground, under these conditions.

X Q. 1121. How could you check those results, Mr. Kelley?

A. They could be checked by means of an airplane and a suitable calibrated receiver by means of which relative values could be plotted.

X Q. 1122. And that would, however, be only approximate in its correctness, would it not?

A. Well, it would be limited to the error in precision of measurement, of course.

X Q. 1123. Which would be greater taken under those circumstances, than under more convenient circumstances, would it not?

A. I am not able to say what the error would be.

X Q. 1124. Did you ever try to make precision measure-
[fol. 394] ments of that kind in an airplane?

A. No, sir.

X Q. 1125. Do you know what the angle at which it is desirable to propagate these waves is?

A. That angle is generally ten to fifteen degrees, and is based on experience as to what it should be because the transmission through space, that is, in the intervening region, has been and still is subject to experimentation and gathering of further knowledge.

X Q. 1126. It varies with a number of factors, does it not?

A. Yes, sir, it would vary with a number of factors. And it is with respect to these factors that I am referring when I speak of the experimentation and the increase in knowledge as time goes on due to the accumulation of data.

X Q. 1126A. The desirable angle of propagation of the waves varies with frequency, for example?

A. Well, the main factors involved, or, rather, the main factor would be the action of the ionized atmosphere which is utilized in the transmission of these waves from the transmitter to the receiver, and the altitude which varies, and, indirectly, the frequency comes in there, because different wave lengths we reach to different heights, so to speak, in this ionized atmosphere, and altogether it is a variable factor.

X Q. 1128. It depends upon the distance between the transmitter and the receiver?

A. Yes, sir, that is a factor.

X Q. 1129. Depends upon the time of day?

A. Yes.

X Q. 1130. Time of year?

A. Yes, sir.

X Q. 1131. And it is a rather difficult thing to determine
[fol. 395] just what is best under all circumstances, isn't it?

A. Well, these factors, as I think we both agree are variable, and one has to accommodate the conditions of sending and receiving, as far as possible, to these factors.

X Q. 1132. Can you state the circumstances under which it would be preferable to propagate the radiation at, say, 18 degrees, rather than at 10 degrees?

A. No, I can not give it to you as detailed as that, no, sir.

X Q. 1133. As to the direction of the propagation from the

antenna, that also depends upon a number of things, does it not?

A. Yes, that would obviously depend upon a number of things, yes, sir.

X Q. 1134. It does not merely depend upon the angle between the wires, does it?

A. The angle between the wires is one factor.

X Q. 1135. Is one factor?

A. Yes, sir.

X Q. 1136. Height above the ground in wave lengths is another factor?

A. Yes, sir.

X Q. 1137. Character of the ground is another factor?

A. Yes, sir.

X Q. 1138. Now, with reference to one of these factors, namely, the height above ground in wave lengths, will you please refer to Plaintiff's Exhibit 13, tabulations respecting defendant's antennae? You will find that near the bottom of sheet 1. Take antenna No. 1, the height above the ground is 80 feet, and the height in wave lengths is .83 wave lengths, is that right?

A. That is right, that is correct.

X Q. 1139. And No. 2 original, in feet, 80 feet?

A. Yes, sir.

X Q. 1140. Height above ground 1.2 wave lengths?

A. Yes, sir.

[fol. 396] X Q. 1141. No. 2 rebuilt, still 80 feet above the ground?

A. Yes, sir.

X Q. 1142. And in wave lengths, 1.19 wave lengths?

A. Yes, sir.

X Q. 1143. And so on. They are all 80 feet above the ground, are they not?

A. That is correct; all but No. 6; that is 70 feet.

X Q. 1147. If the wave length is different, the height above ground in wave length, assuming the same number of feet, would be different, would it not?

A. Yes.

X Q. 1149. So that, as far as these antennas, with the exception of No. 6, are concerned, the height above ground in feet was not varied?

A. So it appears from the tabulation, yes, sir.

X Q. 1150. And yet the height above ground in wave lengths is an important factor, is a factor, in any event, in the angle of the beam?

A. Yes, sir, because the difference in path of the radiation and the image is dependent to some extent on that.

X Q. 1152. Doesn't it seem reasonable to you that in view of that, if one of the purposes in the design of the defendant's antennas was to control the beam of radiation, control the angle of the radiation, there should have been some more or less definite relation between the height of the antennas above ground and the wave length used?

A. Well, as I think we are agreed, I didn't have anything to do with the design of these antennas, so I can not say that of my own knowledge.

X Q. 1153. I am using "design" in the same sense that you used it in your direct examination.

A. Possibly not to control actually the specific angle, but nevertheless, to obtain radiation at an angle to the horizontal since radiation in the horizontal direction would be of no use. [fol. 397] X Q. 1154. As I understand it, you obtain it anyway, regardless, within reasonable limits, of the height above ground, do you not?

A. Yes, you must get a tilt to the beam.

X Q. 1155. And differences above the ground with respect to wave lengths, the effect of that, I think you stated a few moments ago, is to vary the angle of the beam?

A. It would have some effect on it; I am not prepared to state in detail what that effect would be.

X Q. 1156. Isn't there another factor that we haven't considered, if it is desired to obtain the greatest propagation possible at any definite angle; in the case of a double V antenna, should there not be a change in the spacing between the two antenna units?

A. The change in spacing—there would be required a very slight change in the spacing between the antenna units; no change at all would amount to being impractical.

X Q. 1157. But in this case, in each instance with defendant's double V antennas, the two separate units are separated an integral number of quarter wave lengths, are they not?

A. Approximately so, and it need only be approximately so, and as I stated this angle is a small angle, and the difference of the hypothenuse to the side of the small angle is extremely small; it is practically negligible.

X Q. 1158. Will you please refer to your answer Q. 393 (R. p. 316). At this point, you were discussing the third Carter patent in suit, and pointing out the passages from the patent which indicated to you that he intended radiation in the plane of the bisector of the angle. In answer to that question, you quoted:

[fol. 398] " 'Thus, in Figure 8, each of the radiating units A, B, shown in plan view is provided with a reflecting unit a, b. By means of branched transmission lines, as shown diagrammatically at T, each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves upon the units.' "

Then you stated:

"This again means that the radiation is predominantly in the plane of the wires."

Then you stated again:

"Again, on page 3, line 124",

and again quoting from the patent,

" 'By making the phase difference between each of the units equal to 2 pi S divided by lambda, where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression.'

"This again teaches the same thing as the other passages which I have read," the last remark being yours.

[fol. 399] Now, as I understand it, and will you tell me whether I am right or not, please, you were there using the fact that Carter said the spacing between the antenna units should be so related to the phasing of them that the result would be expressed by the formula which you quoted, 2 pi S over lambda?

A. Yes, sir.

X Q. 1161. Indicating that he expected horizontal radiation?

A. Well, he so states.

X Q. 1162. And that is the spacing and phasing that defendant uses in its antennæ?

A. Approximately that spacing and phasing. But, as I pointed out with a small angle which the beam goes out in, the difference in spacing is equal to the cosine of the angle of radiation, which, for a very small angle is almost a unity; it departs very slightly from it.

X Q. 1164. In Defendant's Exhibits S and T in deriving the right hand figures, did you not first make the calculations which gave the left hand figures?

A. You understand, I did not make the calculations myself, but I had them made, and I understand those left hand figures were first calculated.

X Q. 1166. And were calculated as a step in arriving at the right hand figures, is that correct?

A. That is correct, yes, sir.

X Q. 1167. Now, you were asked three questions, namely, questions numbers 395, 396 and 397 (R. p. 318), as to whether certain testimony of Mr. Hogan was in your opinion consistent with the passages in the third Carter patent, which you had read, and you stated that in your opinion that testimony was consistent with those passages in that [fol. 400] it indicated the intended radiation in the plane of the antenna.

Now I wish to read to you something else from Mr. Hogan's direct examination, in answer to Q. 79 (R. p. 187), where he said:

"In the operation of a double V antenna such as we have represented by Model, Exhibit 29, the principal radiation of the antenna itself is in the geometric line of the bisector, that is to say, a horizontal beam is produced in so far as the cooperation of the antenna elements themselves are concerned. If a pair of V's of that kind were in space so that no conducting bodies were in their neighborhood to interfere with the direction of propagation, the energy would be concentrated along the geometric line of the bisector, speaking both vertically and horizontally. In practical use the antennas are set up on poles, usually about 80 feet high. Carter says at page 3, lines 58 and 59, that 80 foot poles or masts may be used to support the wires, and

that is a common length. In that case, with the range of wave lengths that is common in short wave transmission over great distances, the wires are, generally speaking, from three-quarters of a wave length to a little over one wave length above the ground. In a case of that kind, if one considers distances a little way beyond the antenna itself and in the direction of propagation, it is not hard to see that following a diagram such as that of Fig. 7, some energy is projected downward to the ground, not directly along the line of the bisector, the geometric line of it. That en- [fol. 401] ergy going down from the end of the antenna is reflected from the ground at an equal angle, and depending upon the character of the ground its phase is changed. The reflected energy combines with the energy radiated from the antenna itself and goes off into space, and the practical result of a set-up of this kind is that the beam from the antenna, instead of being projected along the geometric line, is actually tilted up at some distance from the antenna."

Do you agree with that statement?

A. Yes, sir, that is what I had to say about the cooperation of the antenna with its negative image, but that is not taught in the third Carter patent, however.

X Q. 1169. Did I ask that last part, Mr. Kelley, whether it was taught in the third Carter patent?

A. I am sorry, Mr. Blackmar.

X Q. 1196. Will you refer, please, to the second Lindenblad patent, Plaintiff's Exhibit 4? With reference to Fig. 2, is there anything shown in that structure, or as described with respect to that structure, which will prevent the formation of standing waves on the antenna wires 2 and 4?

A. My understanding of the specification as a whole, it refers to traveling waves, an antenna of the traveling wave type, and Fig. 2 is one of the theoretical figures in connection with describing the ultimate result, which is, as I understand it, Figs. 3 and 5.

X Q. 1197. Let me read to you, commencing at line 17 on page 1 of this patent, "My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and [fol. 402] which gradually diverge to a much wider spacing at their other ends." Is that a description of Fig. 2?

A. That could describe Fig. 2, yes sir.

X Q. 1199A. Then commencing at line 32, he states:

"Reflection will cause a standing wave, instead of a traveling wave, and result in radiation sideways from the antenna. Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet."

Do you understand that that describes the action of an antenna with standing waves on it?

A. It describes an antenna with standing waves on it, but the statement is not necessarily correct.

X Q. 1200. All right, we may come back to that. Then he goes on:

"However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention."

A. As I understand it, in other words, he is here treating standing waves as something undesirable, he doesn't want them, it is very clear——

X Q. 1202. I hadn't asked a question.

A. I am sorry.

X Q. 1203. With the arrangement of Fig. 2, I think I asked you this before, would there be standing waves on the wires 2 and 4?

A. It would depend on how long the wires 2 and 4 happened to be.

X Q. 1204. And Lindenblad states, and it is pointed out, [fol. 403] that with this arrangement, if they were made long enough to have traveling waves, the spacing at the outer end would be so great as to be impracticable?

A. That is right, that is what he is trying to explain, as I understand it.

X Q. 1205. That is one of the things he is trying to explain.

A. I understand it is the main object.

X Q. 1206. That is your opinion. In your direct examination, in answer to Q. 336 (R. p. 305), when you were discussing Fig. 2 of this Lindenblad patent, you stated that the result "even if the radiation were predominantly along the bisector of the system, would be bi-directional"——

A. Assuming that there were standing waves on the wire.

X Q. 1207. You pointed out as one indication to you that

Lindenblad was proposing to use and was only interested in using traveling waves, his statements as to the use of an impedance matching device, or non-use of an impedance matching device?

A. That was one.

X Q. 1208. You said, as I understood you, in substance, that the absence of an impedance matching device which Lindenblad states as one of his objects is an indication of a traveling wave antenna. That is a correct statement of a portion of your direct testimony, as far as you recall it, is it not?

A. Yes, sir, I am referring to Fig. 2, as I understand it.

X Q. 1209. In other words, you are applying that only to Fig. 2, is that right, that object of the invention? Is that what you meant by your last answer?

A. That is what I meant by my last answer, and I read a whole paragraph on which I commented at the time, and it included not only impedance matching, but also the matter of tuning which, of course, is associated with the standing wave antenna.

[fol. 404] X Q. 1210. Do you remember whether you read this, commencing at line 116 of page 1:

"If the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may prove desirable to employ an impedance matching device between the transmission line and the antenna, as is indicated by the impedance matching unit 16, shown in Fig. 2."

Do you remember whether you read that on your direct examination?

A. I do not recall that I did.

X Q. 1211. What is meant by an antenna being relatively small, so that only a small portion of the energy is radiated?

A. A standing wave antenna.

X Q. 1212. And in the case of Fig. 2 of this patent, if the transmission line is long, that is, electrically long, would it not be desirable to use an impedance matching device, such as 16, I think it is, whether the antenna were a standing wave antenna or a traveling wave antenna?

A. It would depend upon whether or not there was a mismatching of impedances, and as I understand Lindenblad's

teaching in this particular patent, he does do away with that, but I think it would be desirable.

X Q. 1213. In other words, it would not make any difference with an antenna like that shown in Fig. 2, whether you were using it as a traveling wave or a standing wave antenna, so far as the desirability of using an imped- [fol. 405] ance matching device at that point is concerned?

A. An impedance matching device would be apparent for the two cases, because for the standing waves tuning and adjustment would also be desirable.

X Q. 1214. But there would still be the impedance matching device?

A. There could be an impedance matching device, yes, sir.

X Q. 1215. Now, the Lindenblad patent does state that it may prove desirable to employ an impedance matching device under certain circumstances?

A. Yes, sir, in the passage that you just read to me.

X Q. 1216. Now, in Fig. 2, I think you have suggested that if the antenna were long enough it would have substantially only traveling waves on it?

A. Yes, sir.

X Q. 1217. Now, supposing it were, we will say, five wave lengths long, what would it be, a traveling wave or standing wave antenna?

A. In my opinion, a standing wave antenna.

X Q. 1218. What about ten wave lengths?

A. Also standing waves. And you understand when I say that, predominantly so, because in any antenna that is radiating, there are partial traveling waves due to the fact that some of the energy is radiated and can not be reflected back to the source, and therefore the balance, so to speak, of the energy flowing out toward the end which is not converted into standing waves by reflection—since that reflection is reduced by radiation, there will be partial standing waves always, and, as the length of the wires are increased, the opportunity to radiate is greater since there are more—since the wires are more extended, and consequently, as you increase the length of the wires, this partial condition becomes more and [fol. 406] more complete in the direction of traveling waves.

X Q. 1219. As a matter of fact, in standing wave antennas as a result partially of this effect that you are speaking of, the distribution of current along the wire is not truly sinusoidal?

A. There is attenuation along the line.

X Q. 1220. And that affects the distribution of current, does it not?

A. That expresses in one way, the distribution of current.

X Q. 1221. I hand you Defendant's Exhibits CC and DD. Do you know what the units along the lines of the bisector in these diagrams are intended to represent?

A. So far as I know, they are arbitrary units and they are supposed to represent relative power.

X Q. 1222. The individual units are, so far as you know, arbitrary units?

A. I don't recall at the moment just what they are, but I assume that they are arbitrary merely for showing the relative values of power in different directions.

X Q. 1223. Do you know what the concentration, if any, of the relative power in planes other than those of the wires would be in these cases?

A. I have also had prepared a relative distribution of the power in the vertical plane, through the axis of the conductor system (through the bisector of the angle between the wires), that is, one exactly at right angles to this, and if you wish, I can produce it. This is in the plane of the wires.

X Q. 1226. Can you tell me approximately, or in general terms, the nature of that showing that you speak of?

A. Well, it would be a little difficult to describe it without producing it. It is all prepared, and I think that would be a very clear showing. In general, although this is not a complete description of it, I can not remember all of the details, [fol. 407] offhand, but in general, it would show that radiation is not predominently along the axes of the conductor system.

X Q. 1227. That is, in the vertical plane that you speak of?

A. In the vertical plane. There will be another.

X Q. 1228. Is that true of both the four-wave-length wire and the eight-wave-length wire, with this spacing?

A. Yes, sir, as I recall it.

X Q. 1229. Now, with respect to the diagrams that you have before you, Defendant's Exhibits CC and DD, can you state at all what the radiation pattern would be in that plane, if the wires had traveling waves rather than standing waves on them?

A. The wires are open ended, and one diagram is for sides four ways lengths long, and the other for sides eight wave lengths long, and in accordance with Mr. Hogan's interpre-

tation of Fig. 2 of the second Lindenblad patent, it would, of course, have standing waves on them, but if you mean to produce a traveling wave deliberately without consideration of what Lindenblad figures, to simply terminate the wires—is that what you mean?

X Q. 1230. That could be done, by a termination resistance?

A. Yes, but that would no longer be the Lindenblad antenna. I would not say what they would be, except that one of the opposite directions here, the radiation, say, to the rear, would be considerably reduced, and it would be mainly in the other direction.

X Q. 1231. To the left, as you look at the diagram, of the center vertical line of the diagram?

A. The left of the center vertical line of the diagram, that is right, and the radiation would be confined largely to the right hand section.

[fol. 408] X Q. 1233. And would not the pattern be, in general form, approximately similar to the right hand half, for example, of that pattern?

A. I would expect it to be quite similar to it.

X Q. 1234. On those exhibits, is there sideways radiation?

A. Yes, there is quite a little sideways radiation.

X Q. 1235. How are you interpreting my question as to what I mean by sideways radiation?

A. Well, I would interpret it to mean radiation other than on the axis—or the direction of the axis of the conductor system.

X Q. 1237. In discussing this patent, in answer to Q. 329 (R. p. 303), after reading a portion commencing at line 47 of page 1 of the patent, you stated:

"To paraphrase what he states in this passage, he recognizes that he must have the antenna long enough to consume a very large part of the energy."

In that statement you were assuming, weren't you, that the antenna was to be a traveling wave antenna;

A. Yes, and by "consume a very large part of the energy," I meant that a large part of the energy would be radiated.

X Q. 1238. Are you familiar with the Marconi beam type of antenna or the parabolic reflector type?

A. I have had no experience with them, sir.

X Q. 1239. Have you any idea what has to be done with those antennas to tune them?

A. I don't know the details, if that is what you mean, of tuning.

X Q. 1240. Do you know whether it is an easy and simple thing to do or not?

A. I believe it would not be very easy.

[fol. 409] X Q. 1241. It would not be as easy, for example, as tuning a standing wave antenna of the type of Fig. 2 of this patent, would it, assuming that that is a standing wave?

A. Assuming that it is a standing wave antenna, since you would only have to tune in one place, it would be easy to that extent.

X Q. 1242. And if you changed the wave length applied to such antenna, the returning would not be very difficult, would it?

A. No, sir, providing in the design of the tuning adjustment, provision was made for that.

X Q. 1249. Let us confine ourselves then to Fig. 2 of the second Lindenblad patent. Assuming that the antenna is tuned in Fig. 2 so as to be, say, 10 wave lengths long—I may be using tuning in a very popular sense, but with these long wires, that is more or less correct, isn't it?

A. Yes, sir, I agree to that.

X Q. 1251. And you change the frequency so as to make the wave length longer, lessen the frequency; now, if that wave length were in the neighborhood of ten per cent longer, the antenna with its prior adjustment, would be nearly tuned to the new frequency, would it not?

A. As only respects tuning?

X Q. 1254. That is all I am talking about, tuning?

A. Yes, that is right.

X Q. 1255. Speaking of tuning, and only tuning, does this statement, on page 4 of the First Lindenblad patent, apply generally to the type of antenna shown therein, and in the second Lindenblad patent, commencing at line 10:

"This tuning need not be great in range, though the antenna structure will cover a great wave length range, be-

[fol. 410] cause the adjustment can be made for a different number of half waves in length whenever necessary to accommodate a desired wave length."

A. There is an added element in that passage that you read to me, referring to, as I understand it, adjustment other than tuning, and if we confine our attention to tuning, as you suggested, this would be true of single wire or any standing wave antenna. It could be retuned, if that is what you mean—it could be returned—any standing wave antenna could be retuned.

X Q. 1256. And if it has two or four wires, that process is easier, is it not, than in a standing wave antenna of the type of the Marconi beam antenna, or the parabolic reflector type?

A. Well, you have multiplicity of tuning in the latter case, but I am referring to tuning in general since I understand that is what we are speaking of. If you tune a standing wave antenna to one frequency, it is, of course, not a very difficult matter, provided you have made provision for it, to tune the same antenna to a different frequency.

X Q. 1257. But with an antenna that requires a large number of individual radiators, that is quite a little harder, isn't it, than one that requires only two or four?

A. By virtue of the fact that you have more places to tune.

X Q. 1258. And in the case of an antenna like the Marconi beam, you have a great many places to tune, have you not?

A. Yes, of that particular type, yes, sir.

X Q. 1259. In fact, there are 30, maybe 60, individual radiators?

A. Depending on how many radiators you have because you have to tune each individual one.

[fol. 411] X Q. 1260. Now, you said a few minutes ago that you had charts showing the radiation pattern in the vertical plane comparative to those showing horizontal radiation in Defendant's Exhibits CC and DD. I think you offered also to submit them to me?

A. Yes, sir, I did.

X Q. 1262. Would you mind doing so?

A. I will be very glad to. I would rather refresh my memory on them.

X Q. 1263. These charts that you have handed me are such charts?

A. They are such charts, yes, sir.

Mr. Darby: With Mr. Blackmar's permission, I offer the charts in evidence that Mr. Blackmar has called for the production of. I offer the chart in the vertical plane of the four-wave-length antenna in evidence.

The Witness: Vertical plane through the bisector of the angle or the axis of the conductor system.

Mr. Darby: Through the bisector of the angle or the axis of the conductor system.

(Marked Defendant's Exhibit FF in evidence.)

Mr. Darby: And I offer in evidence chart in the vertical plane through the bisector of the angle or the axis of the conductor system for eight wave lengths.

(Marked Defendant's Exhibit GG in evidence.)

X Q. 1265. In the course of your direct examination, Mr. Kelley, I wasn't sure whether you were making a distinc-
[fol. 412] tion between the terms "radiate" and "propagate", were you?

A. Not intentionally. I did not mean any real difference; I was using the terms interchangeably.

X Q. 1267. In Q. 326 (R. p. 300), you stated that you agreed substantially with the statement made on page 2 of the second Lindenblad patent, Plaintiff's Exhibit 4, commencing at line 93, the place where Lindenblad refers to the image in the ground; and two pages later, you also stated that you agreed substantially with another statement which Mr. Darby read to you, respecting the subject of the image. Would you mind telling me what you meant by "substantially" in these answers?

A. Taking them up in order, the reason I had it "substantially" is because while an antenna such an described on page 2, line 93, the passage which you directed my attention to, where he says that it would function exactly the same as if the two wires were present and in phase opposition above the earth, as they would with one-half of the system removed, and the other half being constructed above the earth and cooperating with its image, the reason I used the qualification "substantially" is this: That in theory, assuming a perfect ground, that is true, and that that is the teaching of the art, and that one would naturally make the step that Lindenblad does in going from two wires excited in phase opposition to the structure where one-half is omitted and the image in the ground furnishes the other half of the system, that is the phase opposition and standing waves, if there are standing waves in the half of the system above the ground. That is true in theory and is the teaching of the art.

With imperfect grounds, it is not quite true, but the teach-

[fol. 413] ing is there nevertheless, and in that respect, I agreed with Lindenblad in both his statement in the patent to which my attention was directed, and also the quotation from a letter of Lindenblad's which was read to me.

X Q. 1268. And does your answer cover wherein you disagree with him?

A. Yes, I think it does. I said that it is true in theory, and it is also an accepted thing in practice in determining what the radiation shall be at a distant point, as a first step, but that imperfect ground might alter it, or would alter the theory in certain respects. You see, what I am trying to do is to make a distinction between the teaching involved and what would actually happen, and in that connection, that the naturalness of this equivalent between the two wires above the ground, as being equivalent to a single wire in a vertical plane above the ground, removing the other wire, but allowing the ground image to take its place. That is a natural step, but due to imperfect ground in actuality this is not always achieved.

X Q. 1270. Now, do you know in general the radiation pattern in free space of a wire four wave lengths long, considering only the principal lobes of radiation?

A. Well, the principal lobes will be inclined toward the wire in both directions, the angle,—I am trying to remember—at an angle of something like 50 degrees, they will be inclined at an angle perpendicular to each other.

X Q. 1273. That is easily ascertained if you wish to ascertain it?

A. Yes, it can be computed.

X Q. 1274. Could you indicate roughly on this piece of paper that I am handing to you the radiation pattern in free space of a four-wave length wire, assuming the line [fol. 414] that I have drawn there as the wire, and taking it in a single plane?

A. Well, it would be very rough.

X Q. 1275. Certainly; I am not asking for accuracy, I am asking for qualitative, not quantitative results.

A. Just the principal lobes?

X Q. 1276. Just the principal lobes, that is all I think we need to consider.

A. This is the general nature of it, rather roughly drawn. (Witness handing paper to counsel.)

X Q. 1277. I will write below this, Mr. Kelley, "Fig. 1." There is already written above it, "4 lambda wire,"

"lambda" being the common symbol for wave lengths, is that correct?

A. That is correct.

X Q. 1279. I will also write above "4 lambda wire" the words "free space" because I understand that the pattern that you have drawn is the pattern in one plane of the wire in free space.

A. Yes, sir, the plane including the wire; that is correct.

X Q. 1281. Now I will draw another line below that on this same sheet, which I will have to describe to you as representing a side view of a V antenna, each wire of which is four wave lengths long and the angle of which is the correct angle to secure the maximum radiation along the bisector of the structure. As a structure, is that clear to you, what I am describing?

A. Yes, sir, but now we are getting into things that I would much rather have computed because rough diagrams like these may be misleading. I would be very glad to have that computed in accordance with your instructions.

X Q. 1282. You are not willing to draw qualitatively on here the general nature of the radiation from such a struc- [fol. 415] ture in free space.

A. It is not a question of willingness, Mr. Blackmar, I want to do everything to help you, but it is a question of being accurate, and I certainly do not want to do something offhand which may lead to an incorrect conclusion.

X Q. 1283. Supposing I take the responsibility for the moment, then, of drawing the pattern and I ask you whether you think it is reasonable, and we will see if we can reach it in that way, and if not, we will drop the subject, perhaps. I hand the sheet to you, having drawn with respect to the wire at the lower left-hand corner of the page two lobes by which I intended to represent the main or principal radiation from such a wire in the plane of the wires in free space.

A. This being a vertical section?

X Q. 1285. Being a side view of a V.

A. Well, with the reservation that I made previously it appears reasonable.

X Q. 1287. I will mark that "Fig. 2" and we will assume that free space applies to that also, since it is under it.

A. That would have to be free space.

X Q. 1288. Above it I will put "V" in quotation marks, "with four lambda wire (correct angle)."

A. Well, I don't know what you are assuming by the correct angle.

X Q. 1289. What I mean by "correct angle" is the correct angle of the V to secure the maximum radiation in free space along the bisector of the wires, in accordance with the teaching of the third Carter patent.

A. Very well, I agree.

X Q. 1291. Now, to the right of Fig. 2 I will draw another wire or another line, marking it "Fig. 3", and I would like [fol. 416] to ask you to indicate on there what the effect is of placing the antenna of Fig. 2 above perfect ground, which I have indicated below the line representing the V antenna, assuming the radiation pattern to be as it appears in Fig. 2 without ground. Do you know what the effect of ground is upon such a radiation pattern?

A. I have already explained that.

X Q. 1293. All right; will you illustrate it now, please?

A. Very roughly.

X Q. 1294. Merely qualitative is understood?

A. Yes.

X Q. 1295. And that is over perfect ground, as I understand it?

A. Yes.

X Q. 1296. Still, to the right of that, I have drawn another line and marked it "Fig. 4", below which I have indicated ground, and I ask you to assume that that line represents the same as is represented by the main lines in Figs. 2 and 3 and also to assume that ground in Fig. 4 is practical ground, for instance, such as there is at Sayville. Can you indicate qualitatively the results in that case as compared with Figure 3?

A. Well, I believe it would be fallacious to represent that even qualitatively because different ground conditions are subject to computation, and, as I mentioned when we started out on these series of questions, it might be very misleading not to compute the results; that wrong conclusions might be drawn from them.

X Q. 1297. Going back to Fig. 1; to the right of that I have drawn another line, writing "Fig. 4" below it, that line representing, as in Fig. 1, a straight single wire four wave lengths long; I have also indicated below that wire a symbol for ground, and I ask you whether or not you can indicate [fol. 417] qualitatively the effect of this ground, considered

as perfect ground, upon the radiation pattern shown in Fig. 1?

A. There again, Mr. Blackmar, if you please, I would much rather do that through computation. I will be very glad to have it done for you.

X Q. 1299. And I suppose your answer would be the same if I asked you to make the same illustration for Fig. 5, which is the same as Fig. 4, except that ground is practical instead of perfect?

A. Yes, sir; you mean by that, well, for instance, the ground at Sayville or something comparable to it be taken?

X Q. 1301. I thought taking it qualitatively it might be possible to avoid the necessity of calculations because this was explained to me by sitting down beside somebody in a few minutes as to qualitative effect.

A. It is very easy, as I stated before, to draw misleading conclusions, since all of these things are subject to computation it seems to me that is the proper way to handle it.

Mr. Blackmar: I ask that the sheet of sketches be marked for identification.

(Marked Plaintiff's Exhibit 36 for Identification.)

X Q. 1304. Referring to Defendant's Exhibit F, is that intended to represent wires of a certain length with respect to the wave length?

A. It is not so indicated on Exhibit F.

X Q. 1305. How about Exhibit G?

A. Judging from the radiation patterns which are on Exhibit G, the sides would be four wave lengths long.

[fol. 418] X Q. 1306. And is that the length of the wires that is intended to be indicated in Exhibit G?

A. I should say so, yes, sir.

X Q. 1307. As to Exhibit G, roughly what is the relation of the spacing between the open ends of the wires of Exhibit G with respect to the length of those wires, about one and four-fifths, something of that kind, roughly?

A. Well, the spacing is greater than the length of either one of the wires and less than twice the length of the wires, something in the middle.

X Q. 1310. I thought engineers always calculated quickly when they had angles like approximately twice 60 degrees, so that they could picture the sines, cosines and tangents.

A. It depends where you are, and when you are trying to

be as careful as I am trying to be you won't make any snap answer like that.

X Q. 1311. I say, it is approximately somewhere between one and a half and two, scaling it with your eye.

A. Yes, that is what it appears to be, but I want to be as accurate as I can.

X Q. 1312. In any event, the spacing at the outer ends of these wires isn't in the neighborhood of one-fifth of the length of the wires, is it?

A. Not at all.

X Q. 1313. And you understand that is what is stated as a suggestion in the second Lindenblad patent, do you not?

A. I want to look at it because that is not the only thing it says.

X Q. 1315. It also says, for example, at page 2, line 120, that "the length of each antenna section should be of the order of magnitude of five to ten waves long".

A. That is of each section in Fig. 3 or 5.

[fol. 419] That is the only one that is more than one section, and "each" would apply only to Figs. 3 and 5.

X Q. 1316. That is the way you construe that?

A. I think that is what it says. The other thing that occurs in this passage in respect to the relation between spacing and length of the wires, while he mentions 1/5 as spacing compared with the length of the wires, there is also included: "while variable over a great range."

I am sure that I do not know what he means by that.

X Q. 1317. It also says that it should be in the neighborhood of one-fifth of the length?

A. Yes, but he also adds the other. So I am not sure what to draw from that.

X Q. 1318. Now, when this Chart, Defendant's Exhibit G was prepared, you understood, did you not, that it would show the absence of radiation in the direction of the bisector between the wires?

A. A substantial absence of radiation, yes, sir.

X Q. 1321. Coming to the third Carter patent, let us start with a single long wire in free space. Suppose it were five wave lengths long; as I understand it, the radiation pattern of that wire in free space would be what is indicated in Fig. 1-b of this patent, except that, of course, the radiation is conical, whereas the figure is a plane figure?

A. Yes, sir, Fig. 1b shows the field type radiation pattern which would be given by computing from the Abraham

formula where n is equal to 10, five wave lengths long, being 10 half wave lengths, and that is from a single wire; and in order to visualize the whole thing in space it is necessary, as you suggested, to consider this rotated around in all directions.

[fol. 420] X Q. 1322. Now, if you take two of these wires, still considering free space and place them at an angle with each other, which is twice the angle alpha as indicated in Fig. 1b, so that the lobes of radiation along the bisector of that angle will add, do you understand the structure that I mean by that?

A. I believe I do, sir.

X Q. 1323. That is like, for example, Fig. 2a of the patent, assuming that the wires of that are five wave lengths long, and the correct angle alpha is used in that case?

A. Yes. Do you mean by alpha the angle of principal radiation determined from the Abraham formula, where you consider the lobes which are most important?

X Q. 1324. I mean the angle alpha as indicated in Fig. 1b of the third Carter patent?

A. Yes, sir, that is right.

X Q. 1325. What happens in that case to the principal lobes of radiation along the bisector of the angle?

A. Speaking from a theoretical standpoint, that is, assuming you can make this angle just exactly right, that would mean that in that direction, that is, along the bisector of the angle, and in the plane of the wires, one of the lobes from one of the wires would add perfectly with a corresponding lobe of the other wire; there would also be in the diametrically opposite direction, a similar addition.

X Q. 1327. What happens with respect to the main lobes in the directions of the bisector of the angle? In one direction, the forward direction, they add, and also that the same effect occurs in the rear direction?

A. In the rear direction, and there will still be principal lobes which will not be in that direction at all.

[fol. 421] X Q. 1328. We are both assuming that the wires are fed in phase opposition, are we not?

A. Why, I am assuming that, yes, sir.

X Q. 1329. Now, that takes care of two of the main lobes from each wire, does it not, the radiation along the bisector line?

A. Yes, sir, that is right.

X Q. 1330. Will you tell me what happens to the remaining two principal lobes with respect to each wire under those circumstances?

A. The remaining two principal lobes radiate off in odd directions which are not on this same line.

X Q. 1332. The other two lobes do not cancel each other, is that correct?

A. No, sir, they form an X.

X Q. 1333. Instead of placing the two five wave length wires at this angle, suppose they are placed parallel to each other, still fed in phase opposition, and staggered with respect to each other, in accordance with Fig. 4 of the first Lindenblad patent, except that the spacing between the wires is made correct for complete addition. I understand that you said that that could be done. A. Yes, sir, that can be done.

X Q. 1334. And do you understand what I mean by that structure?

A. Yes, sir, you are assuming that we forget for the moment the wrong instructions of Fig. 4 of the First Lindenblad patent, and assume the correct spacing.

X Q. 1335. Assuming the correct spacing, that is right?

A. Yes, sir.

X Q. 1336. And that they are staggered?

A. Yes, sir.

X Q. 1337. There is no question about the correctness of the stagger in Lindenblad, as far as you understand, is that correct?

[fol. 422] A. Well, it can't be taken alone, the stagger by itself doesn't mean much unless the correct spacing is also adhered to.

X Q. 1338. With that structure will you please tell me what the effects are on the four main lobes from each of the wires as to the radiation pattern of the antenna?

A. You mean just in a general way?

X Q. 1339. Yes.

A. Generally speaking there would then be appreciable cancellation of the two oppositely directed lobes and the conjugate set of lobes would add perfectly in the direction of maximum radiation, in the direction of the principal radiation.

X Q. 1340. You spoke of appreciable cancellation, I think, of two of the lobes?

A. Yes, sir.

X Q. 1341. How would that compare with the arrangement that we spoke of for the V antenna with respect to the lobes outside of the bisector line? Is it greater or less than in that case?

A. Offhand I would say that it might be less because in the case with wires formed at an angle to one another, the other principal lobes of radiation, those that do not line up along the bisector of the angle between the wires, go where they will, so to speak, in a deliberate attempt to cheat cancellation. Whatever happens as to miscellaneous addition, taking into account phasing and difference of path of travel, and so on, without having actually gone into that in detail, my impression would be that the cancellation ought to be more complete in the parallel wire arrangement.

X Q. 1342. It is really a little more than an impression, isn't it, because in the parallel wire arrangement the unused lobes, so to speak, are in the exact direction to cancel each other, aren't they?

A. Yes, in the plane of the wires. You understand, Mr. [fol. 423] Blackmar, that that is a pretty thin thing and a loop has some thickness to it to be useful. I think we can agree that in a general way there would be substantial cancellation.

X Q. 1343. So that with the V arrangement there is, as far as main lobes are concerned, more sideways radiation than with respect to the parallel wires?

A. That is my impression.

X Q. 1344. Will you agree with me that nevertheless the power gain in the case of the V antenna correctly located with respect to angle is greater than the power gain of two parallel wires arranged at the proper stagger and spacing?

A. There are all kinds of definitions of power gain and that is something that I would not answer offhand.

X Q. 1345. Do you have any objection to this definition of power gain: The ratio of the power projected in the desired direction from the antenna under consideration to that projected from a half wave di-pole when supplied with the same input power?

A. I would not agree to it offhand because I understand that you are assuming that all one needs to do then is to take these theoretical diagrams and attempt to show from that that it is so. The only reliable way to consider it, it seems to me, is experimentally, in other words, what actual results one gets.

X Q. 1346. Will you turn, please, to your answer to Q. 356 (R. p. 309). At that place you were comparing, I believe, defendant's antenna No. 8 with the third Carter patent in suit and there is a statement there that I think may bear an implication which you did not intend. I will read therefrom:

"This upper left hand figure represents the theoretical radiation,"

[fol. 424] That was with respect to Defendant's Exhibit S, I think.

"or in other words, the radiation in free space from the V of defendant, at an angle of 45 degrees, whereas the radiation in free space, using the angle recommended by Carter of 50 degrees, gives a somewhat greater theoretical radiation in free space, but it is not usable."

That does not mean that the 50-degree angle of Carter is not usable, does it?

A. No, it doesn't mean that. It means that the theoretical radiation is not usable as yet.

X Q. 1347. We spoke this morning of the desirable angle of radiation with respect to the horizontal for the purpose of radio communication or radio signalling and I think you included the angle of ten degrees as one that might be desirable.

A. Well, a range of angles. I said ten to fifteen degrees.

X Q. 1349. Have you any real idea as to what the best angle is, or can't that be stated?

A. I don't think it can be stated.

X Q. 1350. Will you please refer to Defendant's Exhibit S now, with defendant's antenna No. 8 as compared to an antenna with the angle of 50 degrees, what would be the relative effectiveness, according to this chart, of those two antennas at an angle ten degrees above the horizontal, approximately?

A. The curve is very steep in that portion of the lobe. It would be very difficult to determine it accurately. It is pretty difficult to see there is any difference. It would be about the same.

[fol. 425] X Q. 1354. And if that were the desired angle of radiation, so far as this chart shows, there would not be any advantage in using an angle of 45 degrees rather

than one of 50, would there, within the range of approximately that we spoke of?

A. Approximately, no.

X Q. 1355. In discussing this subject of relation between the angle used between the wires and the angle of radiation, of propagation, you stated, in answer to Q. 361 (R. p. 311), which read:

"Now, will you state whether or not the same is true with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

"A. Yes, sir."

Again you were asked:

"Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course, to all of defendant's antennas?

And your answer to that question was:

"Yes, they are typical."

In the first place, by all of defendant's antennas, you understood all of the V's, I assume?

A. Yes, sir, that is correct.

X Q. 1358. Now, the charts referred to in that question were Defendant's Exhibits S and T, is that correct?

A. That is correct.

X Q. 1359. Will you please look at Defendant's Exhibit T, and again assume that the desired angle of radiation is ten [fol. 426] degrees from the horizontal?

A. Yes, sir.

X Q. 1360. Which of those two antenna systems shown in this diagram would be more effective at that angle?

A. The upper right hand one would be slightly more effective than the lower diagram. The upper right hand one would be slightly more effective at ten degrees.

X Q. 1361. Yes, about how much?

A. About two per cent. more.

X Q. 1362. Now, in that case, the difference between the angle of Defendant's antenna No. 2 (speaking of the angle between the wires now) and the angle determined according to the teaching of the Carter patent is .6 of a degree, is that correct?

A. Yes, sir, that is the difference in the angle.

X Q. 1363. Now, as I understand your answer to Q. 366, the same effect would be obtained qualitatively, although not quantitatively even if the angles were just the same?

A. Well, there would be a difference.

X Q. 1365. Between two antennas of the same angle?

A. No, no, not with the same angle—will you please state the question again?

X Q. 1363. (Repeated by the Reporter.)

A. I am afraid I will have to ask you to explain what you mean, because I don't know what angles you are referring to, that is, to what you are actually referring.

X Q. 1364. In your Q. 366, you were asked:

"Are these diagrams"—that is Defendant's Exhibits S and T—"typicaly and apply equally as well, differing quantitatively, of course, to all of defendant's antennæ?

[fol. 427] I understood from that that you mean that all of defendant's antennas utilized the angle which gave them greater radiation at some angle from the horizontal, in spite of some apparent sacrifice with respect to radiation along the bisector of the angle?

A. Not necessarily, I was there referring to the fact that in depending upon radiation at an angle to the horizontal, such as shown in the right hand figures of these exhibits was a departure from the teachings of the third Carter patent, wherein it states that the radiation should be in the plane of the wires along the bisector. That was the meaning of my answer.

X Q. 1365. I think I will have to go back over the few preceding pages of the record under those circumstances. The discussion of these exhibits started in connection with Q. 356 (R. p. 309), where you were asked to explain the diagrams of what is now Defendant's Exhibit S. It commences even a little before that. You said there that an angle of 50 degrees between the wires is the angle that would have been used had the instructions of the third Carter patent been followed, where actually the angle is 45 degrees.

"In defendant's structure, it is 45 degrees. The reason for this being that by using this angle different from the Carter, or the angle recommended by Carter, in his third

patent, a larger lobe of radiation is obtained when an actual structure cooperating with the ground, its image in the ground, radiates at an angle inclined to the horizontal.

"The radiation, the ultimate objective, so to speak, that which goes out to the receiving station, is greater by using [fol. 428] the angle of 45 degrees with the same length of wire than it is by using the same V, but an angle of 50 degrees, as is recommended in the third Carter patent. It was done at an apparent sacrifice as will be seen by comparing the two left hand figures."

Then you go on discussing them further.

Then you state:

"In other words, the upper left hand figure, where the angle is 45 degrees and corresponds in defendant's antenna, the radiation is somewhat less in this direction than it is for the angle of 50 degrees in that same direction, but for the radiation which actually goes out, that is, the ultimate usable radiation, is greater as seen by comparing the two right-hand patterns where the distance numerically is 31 for the upper right-hand pattern and about 28.6 for the lower one.

"Q. 358. If it has been suggested in this case, that by defendant's departure from the angle recommended by the Carter patent in suit by five degrees, the defendant has sacrificed anything in the efficient propagation of its waves, do you agree or disagree with any such suggestions?

"A. I disagree.

"Q. 359. And does this chart which you have been describing illustrate the reason for your disagreement?

"A. Yes, sir, because the apparent sacrifice is turned into a real gain.

"Q. 360. And when you say 'apparent sacrifice', what do you mean? Do you mean apparent from theoretical con- [fol. 429] siderations or from practical considerations?

"A. I mean from practical considerations.

"Mr. Darby: I now offer in evidence the chart referred to by the witness.

"(Marked Defendant's Exhibit S in evidence.)

"The Court: Did the patentee limit himself to that 50 degree angle, or was that just a suggestion?

"The Witness: The patentee gives the proper angle for a given length of side in electrical length in Fig. 12 of the specification, and in this Fig. 12, the angle 50 degrees corresponds to the one that he draws a curve for, so that that is the angle which he says should be used.

"Q. 361. Now, will you state whether or not the same is true with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

"A. Yes, sir.

"Q. 362. Have you made a similar pattern and comparative diagram showing what the radiation pattern would be in direction along the bisector of the angle of the conductors in the plane of the wires, at an angle of the V of 35 degrees such as employed in antenna No. 2, and what it actually is and what it would be in both instances if the angle of the V were 35.6 degrees?

"A. I have had such a diagram made.

"Q. 363. And does the same relation that you have described with reference to Defendant's Exhibit S apply to defendant's antenna No. 2?

[fol. 430] "A. The same considerations apply to antenna No. 2, yes, sir.

"Q. 364. And are the same results obtained?

"A. The same results are obtained, yes, sir.

"Q. 365. And do you draw the same conclusions?

"A. Yes, sir, the two upper diagrams here correspond to defendant, and the two lower, if the angle from Fig. 12 of the third Carter patent were used.

"Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course, to all of the defendant's antennae?

And your answer to that was:

"Yes, they are typical."

Do you wish to change that last answer, Mr. Kelley?

A. Not at all. When I made that answer I was referring to the fact that radiation from all of the defendant's antennae, that is, the ultimate radiation is at an angle to the horizontal, and therefore departs from the teaching of the third Carter patent. With reference to antenna No. 8 and antenna No. 2, that is very specific. The general idea that

there is radiation not in the plane of the wires but at an angle to the plane of the wires was what I had in mind in replying to question No. 366 when I said that these were typical.

X Q. 1366. But that subject had not been discussed in the preceding two or three pages that I read to you, had it?

A. Oh, yes, sir, I think it was. The reference is actually [fol. 431] to the diagrams for two specific antennae, and in the case of those two they were plotted and showed what I was describing.

X Q. 1367. And they both showed a gain in that maximum tilt angle, did they not?

A. That is right, but when I answered the question to which you referred, I had no such diagram to go by; I had to make a general statement, and what I had in mind was the radiation at an angle which was not in the plane of the wires.

X Q. 1368. Yet you said that the diagrams that you had before you were typical of the other antennae?

A. Yes, sir, and they were with respect to this angle of inclination.

X Q. 1368A. And were they typical with respect to the thing you had been discussing on the last two or three pages, namely, that the radiation at the angle was greater in the case of defendant's antenna than it would have been with the antenna of the Carter angle?

A. I do not know; the only two that were plotted were Nos. 2 and 8, and they happen to be the two that Mr. Hogan referred to in his testimony.

X Q. 1369. Are they the only two that he referred to in his testimony?

A. To the best of my recollection they were the only two into which he went into in any detail to speak of.

X Q. 1370. Do you now know whether there would be any difference if similar patterns were made for the other antennas of the defendant?

A. They would all radiate at an angle; I do not know specifically what the relation would be, making the same comparison as shown in Exhibits S and T.

X Q. 1371. Would they all be qualitatively the same kind, [fol. 432] give you more radiation at an angle than you would get with the Carter angle?

A. I wouldn't say that; I do not know.

X Q. 1372. Some of them may be less?

A. It is possible; I said I do not know.

X Q. 1373. And with respect to the distinction between the defendant's antennae radiating at an angle and what is in the Carter patent, I call your attention to the fact that each of these diagrams you had before you, Defendant's Exhibits S and T, showed at the bottom an illustration of what the radiation would be upon a V antenna with a Carter angle when it is over ground?

A. No, sir, Carter does not teach that.

X Q. 1375. Is that illustrated on this diagram or chart?

A. The ground is added in the lower right hand figure, yes, sir.

X Q. 1376. In other words, the lower right hand figure does show what the radiation of a horizontal V antenna with the Carter angle if placed over the ground would be, is that correct?

A. Yes, that is correct, over ground.

X Q. 1377. I think you said this morning that practically all antennas of this type are placed over ground.

A. Yes, sir, we said that practically all antennas are placed over ground, but when we wanted radiation at an angle Carter tells us to tip the whole structure to radiate at that angle.

X Q. 1378. I hand you two sketches marked respectively 1 and 3; I understand that the sketch marked 1 has been plotted to represent the power distribution in the vertical plane for a single V antenna whose wires are 8.14 wave lengths long, the included angle between the wires being 34.66 degrees, the power distribution being illustrated in free space. Does that look like a reasonable plot of power distribution of that character?

[fol. 433] A. It looks reasonable, but one cannot draw quantitative conclusions from it without checking it.

X Q. 1379. And referring to the diagram labeled No. 3, I understand that has been plotted to show power distribution in the vertical plane of the same antenna assuming that it is mounted over perfect ground, does that look like a reasonable change from one to the other, disregarding quantitative values?

A. There is a rather important detail missing on this sketch No. 3.

X Q. 1380. What is it?

A. Namely, the height of the antenna above the ground.

X Q. 1381. What height did you assume with respect to Defendant's Exhibits S and T for the antenna utilizing the Carter angle?

A. I assumed that the height was the actual height of the defendant's No. 8.

X Q. 1382. I am told that in that case not only was it over perfect ground, but it was over perfect ground at the same height as defendant's antenna No. 2 rebuilt.

A. May I make that notation on the sketch?

X Q. 1384. Certainly. With respect to the chart marked 3, you may note on it that it has been assumed that the antenna is 80 feet above ground, in other words, 1.19 wave lengths above ground. I also hand you two more similar charts marked 2 and 4. I understand that these charts are plotted to represent the same characteristics except that the angle between the wires, the included angle, is 40 degrees, which is the included angle of defendant's antenna No. 2 rebuilt according to the stipulated data. There is one thing I wish to mention in connection with the charts and that is that antenna No. 2 is a single V and that these diagrams show the radiation only on one side of the antenna system. [fol. 434] I am going to ask you, Mr. Kelley, some time between now and a few days from now, possibly, to check those diagrams.

A. I shall be very glad to do so.

X Q. 1389. Is there any further information that you need?

A. I don't think of it at the moment, but if I do, I am sure you will be glad to give it to me.

Mr. Blackmar: I offer the chart referred to above, and marked No. 1, for identification.

(Marked Plaintiff's Exhibit 37 for Identification.)

Mr. Blackmar: Similarly the chart marked No. 3, for identification.

(Marked Plaintiff's Exhibit 38 for Identification.)

Mr. Blackmar: Similarly chart marked No. 2 is offered for identification.

(Marked Plaintiff's Exhibit 39 for Identification.)

Mr. Blackmar: And similarly the chart marked No. 4, also for identification.

(Marked Plaintiff's Exhibit 40 for Identification.)

X Q. 1391. You stated, in answer to Q. 405 (R. p. 324): "Defendant's antennæ operate on a different principle from that taught by the third Carter patent in suit". Will you please explain what you meant by that answer?

A. I did explain this in my direct testimony, but if you would like to have me repeat it, I will be very glad to do so. [fol. 435] X Q. 1392. No explanation appears in the answer in its present form, nor any reference to anything else in that answer. In general what were you referring to?

A. I was referring to the teaching in the third Carter patent, and I pointed out, as I recollect, something like eleven instances where it is taught that radiation is to take place in accordance with the third Carter patent teaching along the bisector of the angle formed by the wires, and when those wires are in a horizontal plane, that the radiation is to take place in a horizontal direction in the plane of the wires, and that when it was desired to radiate at an angle other than the horizontal, the whole structure is tipped after the fashion of aiming a rifle, the aim being along the bisector of the angle.

X Q. 1393. I take it that was what you also meant in answer to the next question, when you said they functioned differently.

A. Yes, sir.

X Q. 1394. Is that correct?

A. That is correct.

X Q. 1395. Is that the only difference in principle that you referred to in your answer to Q. 405?

A. Different angles are used in the antenna structures of defendant as well.

X Q. 1396. Does that make them operate on a different principle, in your opinion?

A. Yes, sir, because striving to make the angle such that radiation will be along the bisector of the angle is a different object than the one where the angle is changed for another purpose.

X Q. 1397. Of course, that statement, "different in angle" applies to only some of the defendant's antennæ, does it not?

A. I think it applies to all of defendant's antennæ to a greater or less extent. The chart showing the distribution [fol. 436] of the angles is quite an irregular curve and some are nearer and some are farther away.

X Q. 1398. Some of them are within a few hundredths of a degree, are they not, of the angle taught by the Carter patent? A. Some of them—three of them, I believe, are fairly close to the angle shown on Fig. 12 of Carter.

X Q. 1399. In fact, they are as close as you can determine on that curve, aren't they?

A. Well, considering the scale or magnitude of the drawing, yes, sir.

X Q. 1400. Considering the width of the line, for example, that makes the curve?

A. Yes, you cannot show differences on that chart as small as that.

X Q. 1401. Is there any other reason why defendant's antennæ function differently from the antenna as taught by the third Carter patent in suit other than taking into account the ground reflection?

A. And the difference in angle.

X Q. 1402. The same answer applies to that?

A. The same answer applies to that, yes.

X Q. 1403. Is "horizontal directivity", an ordinary term in the radio art today?

A. Well, I don't know whether there is such a loose definition or expression, I could not say.

X Q. 1404. Now, going back to the previous subject, my attention has been called to the fact that you have not said whether ground effects and differences in angle are the only things that might make defendant's antenna operate on a different principle from that taught in the third Carter patent?

A. I believe I answered that with a "yes".

X Q. 1405. Those two things are the only things?

A. Yes, sir.

[fol. 437] X Q. 1406. Now, suppose you were at a receiving station in San Francisco or in Europe, receiving signals from Sayville, Long Island?

A. Yes.

X Q. 1407. Would you be able to tell, at the receiving station, at what angle from the horizontal those signals were sent out?

A. Not necessarily.

X Q. 1408. At the receiving station itself, could you tell, necessarily or otherwise?

A. I don't know.

X Q. 1410. Please refer to Defendant's Exhibit U, Carter patent No. 2,027,020, issued January 7, 1936. Commencing at line 50 of page 1 of this patent, Carter says, referring to Fig. 1:

"there is shown an antenna system adapted for unidirectional radiation of electromagnetic energy comprising an upper pair of conductors 1 and 2, which are made long relative to the length of the communication wave and disposed in a horizontal plane in V formation at an angle in such manner that radiation occurs principally along the bisector of the angle. This angle depends upon the length of the conductors and the wave lengths in a manner which is fully described in my United States Patent No. 1,974,387, mentioned above."

I think you have stated that that is consistent with the third Carter patent in suit, is that correct?

A. Yes, sir, but he goes on to explain something that is not explained in the third Carter patent in suit.

X Q. 1412. Namely, commencing at line 29, where he says:

"So far, the effects of ground upon resulting radiation have not been mentioned."

[fol. 438] Do you find that statement?

A. Yes, sir, I read that, if I recall, but I am not sure.

X Q. 1414. You will find the matter in your answer to Q. 398 (R. p. 320). It there appears that you read commencing with line 30, where it states:

"In both theory and practice it has been found that the reflections from the ground"

and so forth.

A. Yes, sir, so it appears; I did not recall. It did not make any difference.

X Q. 1415. Now, the subject of this Carter patent, Defendant's Exhibit U, was introduced to you by asking you whether you knew of any public statement made by the pattentee, Carter, subsequent to the date of application of the

third Carter patent in suit, wherein he stated contrary to the statements contained in the patent in suit you have just referred to, and so forth—and I have been reading from Q. 398. Now, I ask you if you know of any earlier public statement made by the patentee, Carter, than that made in this patent, Defendant's Exhibit U, covering the same subject matter?

A. I believe there is something on this subject in the IRE article, which has been referred to already, I believe, earlier in the case,—Plaintiff's Exhibit 20.

X Q. 1418. The Carter, Hansell and Lindenblad article in the IRE proceedings in the fall of 1931?

A. Yes, sir, I do not remember in detail what it said there, but I believe the matter of the ground is taken up in that article.

X Q. 1419. And that is the article that is referred to, is it, in your answer to Q. 443 (R. p. 340), where you stated that you understood the article to deal rather in detail with [fol. 439] the subject matter of the patent in suit?

A. Yes, sir, that was the article to which I was referring.

X Q. 1421. Will you refer to page 1786 of the article, please, the middle diagram of Fig. 7? That shows, does it not, or purports to show, the power distribution in the vertical plane of an antenna placed above ground?

A. Yes, sir, that is right.

X Q. 1422. Then I refer you to page 1825, commencing at the third line of the page. The article states, "Fig. 47 is a contour map showing the power distribution on an imaginary sphere inclosing a complete antenna section. The antenna is considered as being in space far removed from ground. In the actual case the effect of ground must be considered."

Is that substantially what you stated this morning, the last sentence of that paragraph?

A. Generally speaking that is what I have been talking about.

X Q. 1424. You did state that the effect of ground must be considered in the actual case?

A. Well, it is true, and I may have stated it.

X Q. 1425. And is it correct that that statement refers to a figure, namely Fig. 47, which relates to a one bay model D projector?

A. It so states under the figure.

X Q. 1426. Do you or do you not know what a model D antenna is as described, generally described in this article?

A. I believe the model D is the one where the wires are at an angle to each other,—a V-type antenna.

X Q. 1428. And I refer you also to page 1828, Fig. 48, entitled, "Model D projector, power distribution in vertical plane." That shows, does it not, the effect of ground in a [fol. 440] similar way in which it is shown in the right hand figures of Defendant's Exhibits S and T?

A. Yes, sir.

X Q. 1429. Now, I read to you from page 1825 of Plaintiff's Exhibit 20. I want to read the next one or two sentences:

"The effect of ground on a horizontally polarized wave is such as to cancel radiation at zero angle to the horizon. Fig. 48 is a polar diagram showing the power distribution in a vertical plane when the antenna is located over perfectly conducting ground and over sandy ground such as at Rocky Point."

That is the figure we just referred to?

A. Yes, sir.

X Q. 1431. Now I want to take up the Abraham articles of 1898 and 1901. Is it not customary in engineering mathematics to use Greek letters to represent an angle?

A. Oh, yes, sir, you have quite a range of choice in symbols that you may use.

X Q. 1433. And symbols alpha, theta and phi are often used to represent angles, are they not?

A. Well, they were used by Abraham and they were used by Carter; and also theta sub zero in one case.

X Q. 1435. That is a difference you didn't point out between Abraham article and Carter, the theta sub zero?

A. Well, such difference would be a minor one.

X Q. 1436. Just about equally as important as the other differences?

A. Not necessarily, after all, there are quite a few letters in either the Greek alphabet or our own.

X Q. 1437. Or empirical symbols, so to speak, even?

A. Yes, sir, that is quite a range there.

[fol. 441] X Q. 1438. Both of these Abraham articles deal, do they not, with radiation from a single wire or a single conductor?

A. Yes, sir, that is true.

X Q. 1439. In answer to Q. 433 (R. p. 335), you referred to a single wire excited in its harmonics as a decidedly directional radiator. Am I correct in believing that you meant by that that it would have a radiation pattern as to its principal lobes, such as that of Fig. 1a of the third Carter patent in suit?

A. Or more accurately Fig. 1b.

X Q. 1440. Yes, I said as to its principal lobes.

A. Yes, sir, as to its principal lobes, that is all right.

X Q. 1441. And it also has additional lobes as indicated in Fig. 1b?

A. Yes, minor ones.

X Q. 1442. And those lobes, not only the minor lobes, but the principal lobes are conical, around the wire?

A. Yes, in other words, it does not matter, considering the wire as an axis, what angle you consider going around, in other words, it is cylindrical in nature.

X Q. 1443. Of course, that assumes also, doesn't it, that you are applying only one frequency to the wires?

A. Well, naturally, a frequency corresponding to the length of the wire in half wave lengths.

X Q. 1445. It assumes one frequency of that character is applied to the wire, does it?

A. Yes, one frequency.

X Q. 1446. Defendant's Exhibit W shows a difference, whether it is apparent or otherwise, between what you have labeled as the Carter angle, using the empirical formula, and what you have labeled the Abraham angle?

A. Yes, sir.

X Q. 1448. Over what range of wire lengths, in terms of wave lengths, does that difference appear?

[fol. 442] A. I believe I explained that in my direct testimony, that at a length of something in the neighborhood, of two wave lengths, the two curves merge as the length of the wire, in wave lengths, is made longer, and when it is made shorter there is a larger and larger discrepancy.

X Q. 1449. All of defendant's V antennas utilize wires which are more than two wave lengths long, do they not?

A. Yes, sir.

X Q. 1450. And above two wave lengths the two curves merge, as far as we can tell from this diagram, do they not?

A. Yes, sir.

X Q. 1451. Is there any formula given in either of the Abraham articles by which the angle of principal radiation can be determined without going through a rather complex mathematical computation?

A. The formula itself gives the angle of principal radiation and anybody at all familiar with the elements of mathematics should know how to find it. It does not have to be shown.

X Q. 1452. I am only questioning the use on here of the term "Abraham angle". I am not so sure that it is, in my opinion, proper, because, as I understand it, and correct me if I am wrong, the formula that Abraham gives is a formula which, if plotted for any particular length of wire, will show the radiation pattern of that wire?

A. That is correct.

X Q. 1453. And that the way in which you tell the angle of radiation of the principal lobe is by determining the maximum, or a maximum maximorum from that formula, is that correct?

A. That is correct.

X Q. 1454. That is, there are several maximum points corresponding to the corresponding lobes?

A. Yes.

[fol. 443] X Q. 1456. And to determine the proper angle for the main lobe, you have to determine the largest maximum?

A. Yes, sir, a very simple procedure. I mean, the presence of the formula itself tells the whole story, and inspection alone will tell you what the principal lobes are, or you might apply the elementary principle of differential calculus, where one determines the maxima by process of differentiation.

X Q. 1457. Will you please refer to Q. 440 (R. p. 339). As I understood the testimony at that point, you were suggesting that the Carter empirical formula was not correct, or was not necessarily correct, I don't know which, for points between wires of an integral number of half wave lengths long. Am I correct in that?

A. Yes, sir, you are correct in that.

X Q. 1458. Which? That it is not correct, or that it is not necessarily correct?

A. That it is not correct, because it is based on the Abraham formulæ which are correct only for an integral

number of half wave lengths, that is, you have discrete points.

X Q. 1459. Can you tell me or can you show me, for example, on Defendant's Exhibit W, by how much the formula determined according to Carter's angle would be incorrect at say the point between 6½ and seven wave lengths?

A. I cannot draw it on the curve from memory. Now, the difference is more apparent on the radiation resistance curve, one of which I produced, with a wavy line. What it all purports to show is that one can arbitrarily take assumptions or go beyond the original assumptions, and in this case, having been derived from the Abraham formulæ, [fol. 444] the Abraham formulæ being used, the Abraham formulæ applying specifically to an integral number of half wave lengths.

X Q. 1460. And therefore it would not be safe to assume that what you call the Abraham angle applied at all in the case of wires that were not an integral number of half wave lengths long?

A. No, it would not be safe to assume that, and that is what the angle alpha is based on.

X Q. 1462. Can you tell me by how much the angle departs from the correct angle at a point say between six and one-half and seven wave lengths?

A. No, I do not recall how much. At some point they are calculated and there is a difference.

X Q. 1463. And what is the order of the difference?

A. I don't remember that, it is not a large amount, I can tell you that.

X Q. 1464. Ten degrees?

A. I can not tell you how much.

X Q. 1465. Five degrees?

A. I can not tell you.

X Q. 1466. It might be as much as five degrees.

A. I don't recall, I will get you the information, and I think that will settle the whole thing.

X Q. 1467. I want to see what your recollection is. Might it be as much as five degrees?

A. I don't remember, sir.

X Q. 1469. It might or might not be one-tenth of a degree?

A. Well, that I don't remember also.

X Q. 1471. Defendant's Exhibits Y and Z represent, do they not, half of the radiation pattern from single wires?

A. That is correct.

X Q. 1474. That means one wire in each case?

A. That is correct.

X Q. 1475. As I understand Defendant's Exhibit Z, it is the radiation pattern for a seven and three-quarter wave lengths straight wire?

A. Yes, that is correct.

[fol. 445] X Q. 1476. And Defendant's Exhibit Y is for an eight wave length straight wire, is that right?

A. That is correct, sir.

X Q. 1477. Now, what is the difference in the magnitude of the main lobes in these two cases approximately, the order of difference?

A. Well, they are pretty near the same, one is slightly longer than the other.

X Q. 1478. About two per cent?

A. Very little.

X Q. 1479. And in the case of the seven and three-quarter wave length wire, the radiation at right angles to the wire is considerably greater, is it not, than in the case of the one-eighth wave length wire?

A. I should say not, looking at the diagram. Perhaps I have got the two turned around.

X Q. 1481. The radiation from the seven and three-quarter wave length wire would be considerably greater, in a direction perpendicular to the wire than in the case of the eight wave length wire, would it not?

A. Well, if you are picking a line—something that has no width, and picking it between these lobes, you may be right, but the radiation generally in the direction of right angles to the perpendicular of the wire is substantially less, in the case of Exhibit Z, which is for the seven and three-quarter wave length wire.

X Q. 1482. In the plane perpendicular to the wire, did you say?

A. No, in the direction perpendicular, that is as shown in these diagrams; I mean generally in the direction perpendicular, that is, a line drawn from the center towards 90, in that region.

X Q. 1484. These two patterns do not show the effect, of course, of a V antenna made up from wires of this length, do they?

[fol. 446] A. They show the possibilities of using such wires in various arrangements.

X Q. 1485. They do not show the radiation pattern of two such wires arranged in V formation?

A. Clearly not, because we have already stated that these are for single wires.

X Q. 1486. Have you compared the radiation patterns of an eight wave length V and of a seven and three-quarter wave length V with the angle specified in the Carter patent in each case?

A. There have been many radiation patterns prepared, and I do not recall offhand whether the ones you mention specifically have been or not; I will look and see. If so, you may have them.

X Q. 1487. May I ask what formula was used to compute the pattern of Defendant's Exhibit Z, the diagram of the seven and three-quarter wave length wire?

A. I did not compute these diagrams myself; I had them computed and I can supply you with the computation if you wish.

X Q. 1489. And you do not know what formula was used for that?

A. I do not remember.

X Q. 1490. Referring again to Defendant's Exhibits Y and Z, what is the difference in the angle of the principal lobes of radiation in those two cases, angle with respect to the wire?

A. They are very nearly the same.

X Q. 1491. And what is the difference in angle computed according to the Carter formula for seven and three-quarters as against eight wave length wires, approximately?

A. I should say about a degree.

X Q. 1492. And about how much would you say the difference was between Exhibits Y and Z?

A. Well, they look to me to be pretty nearly the same.

[fol. 447] X Q. 1493. How closely do you think you can judge that from these diagrams with your eye; you estimated the Carter curve with your eye, didn't you?

A. Yes, sir. I can't see any difference, it would be less than a degree, considerably less than a degree.

X Q. 1495. On that basis the Carter curve would depart for the seven and three-quarter wave length case by less than a degree from the correct angle, according to your exhibits, Defendant's Exhibits Y and Z, would it not?

A. Well, it would be determined in that manner, which, of course, is rough.

X Q. 1496. It gives an idea of the order of difference, does it not?

A. At that particular point on the curve.

X Q. 1497. Will you refer, please, to the Bethenod French patent No. 596,737. Do you find any statement in Bethenod as to the length of the wires of his networks?

A. I do, as to the electrical length of the wires of his networks. For example, in the translation, on the first page of the translation, the last paragraph beginning on that page: "A similar arrangement may be provided for the emission of short waves, and, in that case the antenna thus constituted may be operated at the harmonics." That means that it would be electrically long.

X Q. 1499. And that is the basis for your testimony, as I understand it, that the wires of his network are a plurality of half wave lengths long, is that it?

A. Yes, sir.

X Q. 1500. If we assume that is what that means, how short could the wires of his network be and still be excited harmonically, how short in terms of wave length?

A. One wave length.

[fol. 448] X Q. 1501. Now assume, referring to Fig. 1 of this patent, that the system that is harmonically excited is the system 2, 5, 6, 3, considered as a unit?

A. The patent does not so state, that it is considered that way. It says, "the networks." It does not specifically say the networks. On the other hand, he very carefully says that this should be excited at its harmonics, plural, and it is clear from that that he means not only the lowest harmonic but higher harmonics as well, the higher harmonics increasing the electrical length of the conductors.

X Q. 1503. Can you answer my question, making the assumption that I asked you to make, as to what that would indicate as to the length of the wires in the networks 2 and 3, if anything?

A. Well, the details of feeding and whatnot are not altogether clearly shown. He merely shows a wire connected to each pole of high frequency source and he has an optional arrangement for feeding them whereby he locates an oscillator on the pole, one of the poles between the horizontal portions, horizontal wires, also connected to opposite poles of a high frequency generator.

X Q. 1505. Now, supposing you were going to set up one of those systems and wanted to transmit signals from Sayville to San Francisco, and wanted to send them out at an angle of say ten degrees with the horizontal. How does he teach you to set up his system to arrive at such a result?

A. He does not go into such detail any more than the patents in suit.

X Q. 1506. Does he go into them any less than the patents in suit do?

A. At least he does not include errors which are very apparent in the patents in suit.

[fol. 449] X Q. 1507. Now will you read again, please, from the Bethenod patent what he does state as to directivity?

A. Yes, sir, I shall do that.

On page 3, the first paragraph, he states: "Obviously numerous other bearings are possible," that is, other than those shown in the figure where the wires are parallel in a horizontal direction, "particularly the two networks 2 and 3 in Fig. 1 may be arranged vertically"—that is two side by side vertically, still being parallel, "or even inclined, not only with respect to the ground but also with respect to one another so as to obtain directional effects either in a horizontal plane or in the vertical plane or in both planes." And then he adds again: "Furthermore, as is well known, the antenna may in all cases be, if necessary, excited in its harmonics.

X Q. 1508. That is all that he says about directivity, isn't it?

A. Well, isn't that all that he needs to say? We have a reference of a German article by Bontch-Broojevitch, where he goes into considerable detail in the matter of determining what radiation patterns and radiation resistance, and so forth, and the results of various combinations of wires excited at harmonics and arranged with half wave length radiator arrangements.

X Q. 1508. Can you tell me how you would set up the Bethenod system if you wanted to get directivity from Sayville, for example, to San Francisco, following the teachings of the patent?

A. Well, he says that you might incline these networks 2 and 3 with respect to one another, and to be excited in phase opposition, and one can vary the angle between them, [fol. 450] taking into account the ground, in such a way that the desired directional effect would be obtained.

X Q. 1509. And how would you do that following his teachings—what one of those arrangements would you use for example?

A. You would have a choice. I selected the one where the two networks 2 and 3 are inclined to each other.

X Q. 1510. There are, in fact, several ways of inclining them to each other?

A. Yes, quite a few ways. In other words, you do not exhaust all the possibilities by one or two examples.

X Q. 1511. In fact, they can be inclined to each other and still have all the wires parallel to each other?

A. No, I do not understand it that way. He says these two networks may be inclined to one another, and I take that to mean that they are parallel but inclined as to form an angle with each other.

X Q. 1512. If you have one network with the wires horizontal and with the network at an angle, and the other network with the wires horizontal and the network at an angle, are not the two networks at an angle to each other?

A. That is a possibility.

X Q. 1513. And in that case the wires are parallel, are they not, in each of the networks?

A. They could be parallel.

X Q. 1514. In the case that I have given they would be parallel?

A. They would be parallel if it is what I think you mean.

X Q. 1515. And that is another possible arrangement?

A. That is a possible arrangement. There are quite a few possibilities.

X Q. 1516. In fact, they are almost infinite?

A. Oh, no. You would have to not go beyond the region of what one skilled in the art would know what to do, and [fol. 451] the article by Bontch-Broojevitch that I just mentioned supplies plenty of information.

X Q. 1518. Isn't one of his teachings also that the network 3 is to be arranged below the network 2?

A. That is as shown in Fig. 1.

X Q. 1519. That is as shown in Fig. 1, and it is also mentioned in the specification, is it not?

A. Yes, sir, that is one of the arrangements.

X Q. 1520. And is it mentioned as one of the arrangements or is it the only specific arrangement mentioned?

A. Well, apparently he did not find it necessary to illustrate all the other arrangements. He happened to show

this one in Fig. 1, and then he speaks of the others as variations of Fig. 1.

X Q. 1521. If the network 3 were placed below the network 2 could you secure an antenna with its radiating wires in the same horizontal plane, be they either parallel or in V formation?

A. Well, as shown, naturally the wires, considering the two sides of the radiating circuit, are one above the other, but that doesn't prevent one from placing them in a horizontal plane; he openly invites one to do so.

X Q. 1522. But if one is above the other they couldn't be in the same horizontal plane?

A. No, that is what I said; I agreed to that.

X Q. 1523. Does Bethenod say anything about the wires of his networks being inclined with respect to each other as distinguished from the networks?

A. No, but the networks are composed of wires, and the wires of one network of course are fixed with relation to each other, they will be parallel.

[fol. 452] X Q. 1524. Does he indicate that there is any relation between the angle between the wires as they are inclined one to the other and the length of the wires or wave length, or anything of that nature?

A. No, he doesn't go into that; that is something that one can investigate.

X Q. 1525. And when you say that the arrangement of this patent, as I think you did say, is equivalent to the arrangement of the third Carter patent, you are applying to it, I assume, a knowledge that the wires should be at a correct angle, and that they should be at an angle with each other?

A. Well, if your idea of the third Carter patent is a definite specific angle, he doesn't go into that; he doesn't tell you that you must use a certain angle, but that is something for investigation; one can determine that experimentally, or to a certain extent, precalculate it.

X Q. 1526. And in the resume in the Bethenod patent it says nothing about directivity, does it?

A. No, that is simply added with the idea of pointing out one of the things that he had in mind, that is all.

X Q. 1527. Pointing out what he thought his invention was, is that correct?

A. Well, after having described the arrangement that I have been speaking of.

X Q. 1528. Mr. Kelley, we were discussing the Bethencd patent, 596,737, when we closed last night. I asked you to refer to Fig. 1 of this patent, and to consider that the system which is harmonically excited is the system 2, 5, 6, 3, considered as a unit, and then, with that assumption, I asked you what that would indicate as to the length of the wires in the networks 2 and 3, if anything?

[fol. 453] A. You understand, Mr. Blackmar, that the details of the feeding system are not shown.

X Q. 1530. Can you, under those circumstances, answer the question?

A. Well, without knowing the exact length of 5 and 6 and one must assume some reasonable arrangement of feeding, namely, that the feeding wires will be such that while the whole system will operate as you want it to, that is, with the harmonics, that it will produce the harmonics on the horizontal networks 2 and 3.

X Q. 1532. On that assumption, can you state whether anything is indicated with respect to the electrical length of the wires in the networks 2 and 3?

A. As to electrical length that would mean that the wires were electrically long, if they were excited in their harmonics.

X Q. 1535. If the system were excited in its harmonics.

A. Well, these wires are the radiators and they are the things that are excited in their harmonics.

X Q. 1536. Pardon me. I asked you to make a certain assumption, and I think that is disregarding the assumption.

A. I am afraid I don't understand your assumption, Mr. Blackmar.

X Q. 1537. Will you please refer to the other Bethenod French patent, No. 625,293; do you find any statement in this patent, Mr. Kelley, indicating that Bethenod considered the arrangement shown in the figure of the patent was that of a directional antenna?

A. Yes, sir.

X Q. 1538. Please refer to it.

A. On the second page of the translation, the paragraph beginning about the middle of the page:

"It should be noted that the invention may be subject to [fol. 454] many variations or modifications, as far as the

details are concerned: A plurality of antenna arrangements of the same type may be combined at the same station, and suitably oriented with respect to one another in order to obtain directional effects or to make possible multiplex operation."

X Q. 1539. Does that say anything about directivity from a single unit of his antenna as shown in the diagram?

A. No, but the diagram itself shows a directional antenna.

X Q. 1540. That is your interpretation of it, but does that state that the antenna as shown in the diagram of itself is directive?

A. Not in those words, no, sir.

X Q. 1541. Or in substance?

A. In the figure, as I said before.

X Q. 1542. I asked you about the specification?

A. Yes, and the passage which I just read is merely emphasizing the additional directional effects he can get by combination of a plurality of such radiators.

X Q. 1543. By using more than one of them?

A. Yes, but each one being directional also.

X Q. 1544. But the patent does not state that each one is directional also, does it?

A. No, sir.

X Q. 1545. In next to the last paragraph of your answer to Q. 464 (R. p. 354), it is reported that you stated that the patent taught the use of a radiating wire, a plurality of wave lengths long. I think you said somewheres else a plurality of half waves. Isn't the latter the correct statement?

A. Yes, and they, of course, would coincide if you come to two or four half wave lengths. I did not mean to make any such distinction, however. The patent said a plurality of half wave lengths.

[fol. 455] X Q. 1546. Is there anything in the Bethenod patent itself outside of your interpretation of the drawing that refers to the image of the antenna in the earth?

A. The specification does not go into that matter at all.

X Q. 1547. There is nothing in the patent to indicate that Bethenod knew that there was an image in the ground?

A. Oh, yes, sir, the figure in the patent shows the ground, and it was common knowledge with regard to the image produced in the ground, and it was, as I have stated several times, certainly from a theoretical standpoint, it was usually considered to be a perfect ground for determining as a first

approximation the general type of radiation that would be obtained from the system as a whole.

X Q. 1548. Now, please answer that question again as to whether there is anything in the patent to indicate that Bethenod knew there was an image of his antenna in the ground?

A. Yes. The representation in the figure, and the showing of the ground in the figure, in my opinion, was sufficient.

X Q. 1549. Sufficient to show that he knew there was an image, do you mean?

A. Yes, sir, that he was aware of the image that would be in the ground.

X Q. 1550. In other words, the mere fact that he shows the ground in the drawing, is that correct?

A. Yes, sir, coupled with the general knowledge of it. I am referring now to the Abraham article of 1901, where that idea is very clearly expressed, and that is the reason that I applied that knowledge in the case of Bethenod.

The Court: As I understand it, you say that it shows the ground, and from that you deduce that the man was pos-
[fol. 456] sessed of the knowledge of the time, and therefore considered that he knew it. That is what it means to me, anyhow.

The Witness: That is exactly the idea that I wish to express, your Honor.

X Q. 1553. Now, do you find anything in the Bethenod patent suggesting any reason for making his wire more than one-half wave length long, speaking of the radiation wire?

A. Yes.

X Q. 1554. Where?

A. He states at page 2, in the first sentence thereof:

"In order to obtain the greatest radiation efficiency for the antenna, the length of BC should preferably be equal to a whole number of half wave lengths."

X Q. 1555. And that includes one half wave length, does it not?

A. Yes, sir, a whole number.

X Q. 1556. That may be one or more?

A. One or more, yes, sir.

X Q. 1557. Now, would you please tell me, if you can, whether you find anything in there that suggests any desirability of having the wire more than one-half of one wave length long?

A. Well, I have to consider the fact that he uses plural when he speaks of the length of this wire, he says:

"The length of BC should preferably be equal to a whole number of half wave lengths."

I do not think that that rules out additional half wave lengths, in fact, I think it invites the use of additional half wave lengths.

The Court: Then the answer is "Yes".
The Witness: The answer is "Yes".

[fol. 457] X Q. 1558. I think that you also stated that that does include a wire one-half wave length long?

A. Yes, sir.

X Q. 1559. In other words, you cannot say "a whole number of half wave length"?

A. Not very well, sir.

X Q. 1560. Now, does Bethenod in this patent suggest there is any relation between the length of the radiating wire, the wave length that he uses and the magnitude of the angle D, which is the angle between the radiating wire and the horizontal plane?

A. He states, at the bottom of the first page of the translation, that is the last full sentence on the page:

"The portion BC of the antenna may form an angle D of any value from zero to 90 degrees with the horizontal."

He does not state specifically that some particular length is associated with some particular angle.

X Q. 1561. He does not suggest there is any desired relation between the wire length and the length of the wave and the magnitude of the angle; is that correct?

A. Yes, sir, that is correct.

X Q. 1562. Does Bethenod anywhere suggest in this patent that he has devised an antenna comprising two parrallel wires?

A. Yes, sir.

X Q. 1563. Where?

A. He says that the angle D may have any value from zero to 90 degrees.

When D has a value of zero, co-operating with its image, its image being parallel to it, then the system is one of two—the equivalent to two parallel wires, excited in phase opposition.

X Q. 1564. I did not ask about one that was equivalent, Mr. Kelley. Did he anywhere suggest that he has devised [fol. 458] an antenna comprising two parallel wires?

A. He shows it in the drawing.

X Q. 1565. The only two parallel wires in the drawing are the wires EF and AL, are they not?

A. I understood you referred to the radiators, not the impedance.

X Q. 1566. I did. All right, then, where does he show it in the drawing?

A. By showing the position of the ground in relation to the wire BC and stating in the specification that the angle D may be zero degrees.

X Q. 1567. That would give you, as you stated before, an equivalent, in your opinion, of a parallel wire antenna?

A. It is a very definite teaching.

X Q. 1568. A teaching by whom?

A. For example, Abraham.

X Q. 1569. But not by Bethenod? A. It is not expressly stated by Bethenod, but one must assume what is general knowledge.

X Q. 1570. And in order to find in this Bethenod patent, either a parallel wire antenna or a diverging wire antenna or a V antenna, it is necessary to consider the image in the ground, is it not?

A. Yes.

X Q. 1571. Now, will you please refer to your answer to Q. 464 (R. p. 353), where you stated, in connection with this patent, as follows:

"Nevertheless, in considering antennae in relation to the ground, it has been the custom of those skilled in the art first to assume that it is a perfect ground", and so forth.

I do not find, in that answer, that you have stated that they would assume secondly, or what would occur after [fol. 459] making the first assumption. Will you please explain that?

A. Well, I did not add that, because, as I explained in the course of my direct examination on this subject, I was considering what the Bethenod patent teaches one skilled in the art, and when one skilled in the art considers the radiating system with the wire above the ground, it has been the custom to consider the ground as a perfect reflector for electric waves.

Of course, after that, when one considers the actual installation, there are many other things to consider, but I was not considering such things, I was considering the teaching, and that is what is more than a suggestion as to the radiation that would be obtained if, instead of the wire co-operating with its image in perfect ground, the two wires were placed above the ground, and I think what I had in mind was very clearly brought out in the second Lindenblad patent, where Lindenblad starts out first with two wires excited in phase opposition above the ground, and then includes, as part of his disclosure, the use of one-half of that system above the ground, and the other half being omitted, since the half that is omitted will constitute then the image in the ground.

Of course, aside from that teaching, actually the ground encountered is imperfect and the exact equivalents of the radiation pattern will not hold. I am speaking only of the teaching involved, the fact that it is something more than a suggestion to go from one to the other.

X Q. 1571. Are you finished?

A. Yes, sir.

X Q. 1572. Then, as I understand it, in that answer you said first they would assume perfect ground?

A. Yes, sir.

[fol. 460] X Q. 1573. And discussed that, and if you had completed that thought, you would have said that then in the practical set-up it was necessary to consider conditions of actual ground, is that approximately correct?

A. That is correct.

X Q. 1575. Referring to your answer to Q. 473 (R. p. 358), you stated that with respect to defendant's antennas they were placed above the ground—I am not quoting you—they were placed above the ground at a distance of the order of a quarter of a wave length or thereabouts. Will you please refer to the tabulation, Plaintiff's Exhibit 13? The first sheet on the tabulation, the fourth line above the bottom,

indicates, as I understand it, the height of the antenna wires above ground in terms of wave length, is that correct?

A. Yes, sir, that is correct.

X Q. 1576. And those figures run from a minimum, I think, of .49 wave lengths with respect to antenna No. 8 to a maximum of, I think, 1.49 wave lengths in the case of antenna No. 6. Is that correct?

A. Yes, sir.

X Q. 1577. Are any of the defendant's antennas therefore a quarter of a wave length above the ground?

A. No, sir. In that answer I was speaking generally and from memory and did not attempt to be exact in saying a quarter of a wave length. The idea I had in mind was that it was sufficiently removed from the ground to come within the general range that Levy was speaking of.

X Q. 1578. As a matter of fact, they run from two quarter wave lengths to about six quarter wave lengths above the ground, do they not?

A. Yes, something of that order, but Levy's instructions were rather to keep away from the ground, and he men- [fol. 461] tioned a minimum of an eighth wave length.

X Q. 1579. Pardon me, that is not part of the answer to the question, I think. The question was as to defendant's antennas and their height above ground. Levy suggests, as I understand it, on this subject, referring, for example, to paragraph 4B of the resume of the original patent No. 593,570, height between one-eighth and five-eighths wave lengths, does he not?

A. Yes, sir, he does.

X Q. 1580. And a substantial number of the defendant's antennas are outside of that range, are they not?

A. Yes, sir, that is true.

X Q. 1581. Referring to the patent of addition, Levy patent of addition, Fig. 1 of that patent shows as its radiating members, so to speak, two networks, "1" and "2", doesn't it?

A. Yes, sir.

X Q. 1582. Paragraph 4J of the original Levy patent reads as follows: "The application of these arrangements for transmission and reception is envisaged particularly with short waves of less than a thousand meters wave length." Of course waves of 300 meters are less than 1,000 meters wave length, are they not?

A. Yes, sir.

X Q. 1586. And even 300 meters, for example, is a considerably longer wave length than the wave lengths utilized by defendant, is it not?

A. Yes, sir, but these dividing lines are rather arbitrary.

X Q. 1587. Surely; and in fact the dividing line, although it is not a true line, has been shifting over a period of years, hasn't it?

A. It changes quite a lot.

X Q. 1588. What do you find in the Levy patent of addition as to the length of the wires in the networks 1 and 2?

[fol. 462] A. The specification is silent as to the length of the wires of 1 and 2 in Fig. 1.

X Q. 1589. But the original patent, as I think you read, has a paragraph in the resume, namely, paragraph 4D, which indicates in that case a length approximating one-quarter of a wave length, doesn't it?

A. Yes, sir, referring to the figures shown not in the patent of addition, but in the first one I referred to.

X Q. 1590. Now I will ask you to assume that in Fig. 1 of the patent of addition the networks 1 and 2 are composed of wires of approximately a quarter wave length in length. With what position of those wires would you secure the best directivity?

A. Something, I should say, a little greater than 90 degrees.

X Q. 1591. And in what direction with respect to the bisector of the 90-degree angle would that directive radiation take place?

A. It would be in the vertical plane of the bisector.

X Q. 1593. And as far as the horizontal directivity pattern is concerned, what would be the best angle for the two networks?

A. Well, I wouldn't be able to state that offhand. I am sure, however, that I can obtain for you the necessary information. It isn't the sort of thing that can be answered offhand.

X Q. 1594. And if the wires were placed 180 degrees apart, for example, that would approximate what we have been referring to as a di-pole in this case, would it not?

A. Yes, sir, that would approximate a di-pole.

X Q. 1595. Now will you please refer to the Brown British patent No. 14,449. Referring to page 2 of this patent I note that in reading the patent you skipped the two-line para-

[fol. 463] graph commencing at line 12. Will you please read that?

A. "The said wires may be closed at the top or not, and they may or may not be provided with an earth connection."

X Q. 1596. If they were closed at the top, would they be open-ended wires?

A. No, sir, then they would be short-circuited.

X Q. 1597. Do you know what the directive pattern in the horizontal plane of such an arrangement as that of Fig. 1 would be?

A. It would approximate two tangent circles.

X Q. 1598. In other words, approximately the directive pattern that appears in Fig. 1 of the first Lindenblad patent in suit, I think it is?

A. Yes, sir, something like that.

X Q. 1599. And in free space, if this antenna were placed in free space, what would be the principal direction of radiation with respect to the wires themselves?

A. It would be in the plane of the wires, but at right angles (90 degrees) to the wires.

X Q. 1601. Now, refer to Q. 487 (R. p. 364); am I correct in understanding that your answer to that question was intended to apply to the defendant's antennas, in view of the preceding question?

A. I was not referring to the wires of defendant's antennae, no sir.

X Q. 1603. What were you referring to?

A. I was answering a general question without reference to anything in particular except the question itself. The question reads: "Now, what would have to be the necessary relation of the wires of the antennae" in order that radiant action would occur in a direction making the same angle with each conductor?" That is a perfectly general question, [fol. 464] and my answer is: "The wires in that case would have to be parallel."

X Q. 1605. Is it not correct that the defendant uses an arrangement of wires in which the wires are not parallel, yet the predominant radiant action occurs in the direction named, the same angle with respect to each of the two wires of the V?

A. Defendant's antenna wires do not radiate forming the same angle with each of the wires, no, sir.

X Q. 1607. How much difference is there between the angles?

A. The one is a positive angle and the other is a negative angle. The magnitudes are the same but the signs are different.

X Q. 1608. Numerically they are the same but the signs are different?

A. Yes, sir, and that makes the angles different.

X Q. 1609. In other words, take, for example, defendant's antenna No. 8, in which, as I understand it, the wires are at an angle of 45 degrees with respect to each other. Let us first consider the bisector as being in an easterly-westerly direction for convenience of reference, so that one wire is 22½ degrees on the south side of that bisector and the other wire is 22½ degrees on the north side of that bisector. Now, the predominant radiant action takes place from the southerly wire, for example, at what angle to the wire?

A. At 22½ degrees in a conical lobe.

X Q. 1612. And in the case of the other wire what is the direction of the predominant radiation?

A. 22½ degrees in the conical lobe. May I add that the conical lobe, of course, extends all the way around the wire, and that it is not the same direction from the axis in which the reinforcement takes place.

[fol. 465] X Q. 1613. All right, I probably did not go far enough; I should consider the two wires when they are both working together, because that modifies the radiant action, does it not?

A. Yes, you get the combined effect then.

X Q. 1614. And now let us consider the antenna as a V antenna. Possibly, instead of No. 8, we had better take a single V for simplification. But we will assume the same angle, so as to go on without changing our figures. With the antenna set up as a V, what is the direction of predominant radiation from, for example, the southerly wire?

A. 22½ degrees on the north side.

X Q. 1618. And what is the direction of predominant radiation from the other wire with respect to the wire where they are combined?

A. 22½ degrees on the south side of the north wire.

X Q. 1620. Now, will you please refer to the Japanese patent, or to the translation of it, rather. Do you understand from the specification that Fig. 2, that is the upper left-hand figure on the sheet which contains six figures, is a diagram of an experimental arrangement?

A. Yes, sir, I so understand.

X Q. 1622. And does this state what the wave length was in that experimental arrangement?

A. I believe it was stated to be 40 meters.

X Q. 1623. And what is the length, the electrical length of the left-hand wire, the left-hand vertical wire of the two parallel wires in the figure?

A. The left-hand wire would be slightly greater than a half-wave length.

X Q. 1625. And how about the right-hand vertical wire?

A. That is given all values from the same length as the [fol. 466] left-hand wire to the values marked on the figure: 26 meters; 16 meters; 11.86 meters; 8.7 meters.

X Q. 1627. So that in no case is the right-hand wire indicated to be longer than the left-hand wire, is that correct?

A. Not in this figure.

X Q. 1628. Do you consider the vertical wires shown in Fig. 2 to be electrically long wires?

A. Well, I would say that they are electrically long, a half-wave length long is of pretty good electrical length.

X Q. 1629. So that any wire that is at least a half wave length long is, in your definition, electrically long?

A. Well, I would not make a hard and fast rule of it. After all, it is a shifting thing, depending on how you happen to feel about it. That is, it is not something where you can draw an arbitrary line any more than for instance in connection with what is long wave and what is short wave.

X Q. 1630. Now, in this system of this Japanese patent, he staggers his wires at an angle, I think, theta?

A. It is so marked on Fig. 2 and Fig. 1 also.

X Q. 1632. Now, so far as Takagishi describes the action of this antenna, does he sugegst that there is any relation between the angle of stagger and the angle of predominant radiation from one of his wires?

A. No, sir, that is not what he is trying to show in this patent.

X Q. 1633. In answer to Q. 492 (R. p. 366), you stated:

"he offsets them" (that is, the wires) "at an angle with respect to one another in order to obtain his control of direction that I mentioned."

[fol. 467] With the arrangement shown, does he obtain that control?

A. I should say that he would have some control, although I believe it is not particularly good in that respect, but this

is something additional to merely using two electrically long wires in parallel. As he states, he wants to obtain something additional.

X Q. 1634. Now, will you please refer to page 3 of the translation, the page that contains a table near the bottom. Now, with respect, first to the columns of that table, the number of the harmonic represents what, according to your understanding?

A. The number of the harmonic there represents, according to my understanding, a number of quarter wave lengths.

X Q. 1637. And what does the angle against the horizontal plane represent to you?

A. The angle at which the principal lobes of radiation would be sent out with reference to the horizontal plane.

X Q. 1639. In other words, the complement of the angle between the lobe and the wire, is that what you mean?

A. That is correct.

X Q. 1640. On that basis, is the table correct?

A. No, sir, the table is not correct. It so happens that I have not marked in my copy where it is incorrect, but, as I recall, there is one value given which is incorrect.

X Q. 1641. And that table relates, does it not, to radiation from a single vertical wire?

A. Yes, sir, the type of wires, as I understand it, that Takagishi intended to use.

X Q. 1642. But so far as his disclosure is concerned, he makes no utilization of that angle of principal radiation, does he?

A. Well, he doesn't go into it in detail, but he must make [fol. 468] use of it, since he is using the electrically long wires, and he knows of it, because he gives it in the table.

X Q. 1643. Yes, but it does not appear that he considers that that enters into the vertical directivity, that he is securing by the arrangement shown, does it?

A. Yes, sir, I think it does.

X Q. 1644. In the arrangement of Fig. 2, for example, the experimental set-up, he would not be utilizing that, would he?

A. In that particular figure, the wires would not be long enough to give him the inclined lobes, being only a half wave long.

X Q. 1645. Nevertheless, he was intending to secure inclined radiation with that arrangement, wasn't he, as appears from the specification?

A. He was endeavoring to secure control of the angle, and this, as I understand it, was an experiment that he carried out.

X Q. 1646. Yes, an experiment upon which he bases, as I understand, the arrangement he suggests using in the figure, to control the angle of radiation, is that correct?

A. Yes, sir, I think you are correct.

X Q. 1647. You read from page 2 of the translation a statement of the patentee that this invention makes possible efficient communication by adjusting the radiation angle, depending upon the distance between the transmitting and receiving stations. Do you agree that this invention made that possible?

A. Since I haven't tried it, I could not answer your question satisfactorily.

X Q. 1648. As a matter of fact, you stated you were not sure it would work the way he said, didn't you?

A. I am not sure that it would be a very good arrangement. I can see difficulties in it, but I do not mean to say it could not possibly work.

[fol. 469] X Q. 1649. Now, in Q. 495 (R. p. 366), referring to this patent, you were asked:

"Is it or is it not the angle of offset"—(that is theta that is being referred to)—"between the wires in exactly the same sense as the angle alpha is employed in Fig. 4 of the first Lindenblad patent?"

Your answer was:

"It is the angle of offset of the ends of the wires."

But am I not correct in stating that it is not the angle alpha in the sense of Lindenblad with respect to the direction of predominant radiation from the wire?

A. Do I understand that you are doubting the correctness of my answer?

X Q. 1650. No, I am doubting whether you answered the question as asked, that is all. Your answer, I think, is correct.

A. Oh, no, it does not correspond to the angle alpha in the first Lindenblad patent. It is merely the angle of offset of the wires.

X Q. 1651. Will you please refer to the Heising patent, 1,562,961. You referred to Fig. 10 of this patent, and re-

ferred to the lines marked 20 and 21 of this diagram as wires. Do you understand that they are intended to represent plain linear wires?

A. Taken in conjunction with the rest of the figures, I understand that they refer to a transmission line which is loaded; in other words, loaded at sufficiently close intervals, electrically speaking, that it is equivalent to its new line.

X Q. 1652. In other words, line 20, for example, might represent the antenna 2 of Fig. 2 or Fig. 1, or the antenna [fol. 470] of Fig. 4?

A. Yes, sir, that is my understanding.

X Q. 1654. Heising does not suggest, does he, that those wires are plain wires?

A. He doesn't say that they are plain wires, and when I used the term "wires" here, I was thinking of transmission line, which all these figures show where they show the antenna.

X Q. 1655. The type of wire of the antenna that the defendant uses is not of the type of wire there?

A. No, it is not a loaded wire.

X Q. 1656. Will you please refer to Fig. 8? Have you any understanding as to the length of the antenna in that case, in wave length?

A. Yes, sir, 12 wave lengths.

X Q. 1657. Do you know what the frequency involved is?

A. On the same page, page 4, there is a frequency of 50,000 cycles mentioned.

X Q. 1658. How long would you say a 12 wave length wire would be at a wave length corresponding to 50,000 cycles, approximately?

A. It would be 48,000 meters long.

X Q. 1660. Somewhere in the neighborhood of 30 miles, generally speaking?

A. It would be something under 30 miles, but in that general range.

X Q. 1661. Does the angle theta in Fig. 8 correspond to the angle of principal radiation of a plain wire 12 wave lengths long?

A. No, sir, it refers to the angle of principal radiation of a loaded wire 12 wave lengths long.

X Q. 1662. And that follows a different law, does it, as to angle of radiation, from a plain open-ended wire?

A. It is very closely connected with it.

X Q. 1663. How close is this angle theta in the case of Fig. 8?

A. The size of the angle would be different, but you spoke [fol. 471] of the law it followed, not specifically the angle, but there would be quite a difference in the angle. In other words, the Abraham angle, that is to say, the angle of the principal lobe of radiation which one would derive from the Abraham formula on the unloaded antenna 12 wave lengths long, would be inclined to the wire at a much smaller angle than this angle theta, shown in Fig. 8.

X Q. 1664. Does Heising illustrate here standing wave or traveling wave antennas?

A. These are traveling wave antennas.

X Q. 1665. With a traveling wave antenna as described by Heising what controls the angle of radiation from the wire?

A. There are several things that control the angle of radiation from the wire. There is the electrical length of the wire, and also the phase shift along the wire, apparent velocity of the waves on the wire compared with their velocity in free space.

X Q. 1666. Will you please refer to page 3 of this patent, line 102, "When the ratio,"—do you know what ratio he is referring to there?

A. I think I do; the ratio of the velocity in the wire to the velocity in free space, that I have just mentioned.

X Q. 1668. "When the ratio is infinite," that means, does it not, when the apparent velocity of the wave along the wire is infinite?

A. That is right, when there is no phase shift along the wire at all.

X Q. 1669. "When the ratio is infinite the wave front will obviously be parallel to the conductor and the direction of propagation will be perpendicular to the antenna. When this ratio is less than unity, the antenna is not directive."

[fol. 472] Do you agree with that?

A. No, sir, I do not.

X Q. 1670. According to the teaching of what I read to you, however, that means, does it not, that when the apparent velocity of the wave on the wire is anything less than the velocity of light, the antenna is not directive?

A. That is what he says.

X Q. 1672. What is the apparent velocity in the case of defendant's antennas with respect to the velocity in free space, do you know?

A. Well, I have to make certain assumptions. It is very nearly, I should say it would be somewhat less but very close to the velocity of light.

X Q. 1673. That is my understanding of it, but the ratio of that velocity to the velocity in space would be less than unity?

A. Yes, because you have resistance in the wire and that always slows up the wave.

X Q. 1674. And under those circumstances, as stated by Heising, the antenna would not be directive, lines 105 to 107 on page 3?

A. He so states, but he uses a different ratio.

X Q. 1675. What do you mean by a different ratio; he had his antennas using a different ratio, is that what you mean?

A. Yes, taking Fig. 8, for example, that would be something intermediate.

X Q. 1676. I understand that, but your answer might be misunderstood, I think. The ratio that he is referring to in line 106 is the ratio that we were talking about, namely, that of the apparent velocity of the wave to its velocity in free space, is it not?

A. Yes, sir, and also not to have the answer misunderstood, he loads the antenna wire and actually does attempt to increase the velocity. That is the way he uses it.

[fol. 473] X Q. 1677. And that is the way he thinks he can secure directivity?

A. Well, he can secure directivity that way.

X Q. 1679. Comparing the arrangement of Fig. 10 of this patent to Fig. 4 of the first Lindenblad patent, am I correct in understanding that in the case of Heising the cancellation takes place in the direction from the shorter to the longer wire, that is, in the direction 23-22?

A. Well, it isn't a case of a shorter or longer wire, you mean the one that is placed to the left?

X Q. 1680. I was looking at the diagram when I was saying that; cancellation takes place in the direction of lobes 23-22, is that correct?

A. Yes, sir, that is correct, because the wires are cophasially fed.

X Q. 1681. And in the case of Lindenblad, Fig. 4, the cancellation takes place in the opposite direction with respect to the stagger of wires, is that correct?

A. Assuming that they are correctly spaced, and by virtue of the same principle.

X Q. 1713. Do you know where it would be, the principal or predominant radiation?

A. It could be determined. The two diagrams are not resolved into one, and that would have to be done in order to answer your question.

X Q. 1714. In each of these cases, as I understand it, the angle between the wires was chosen, wasn't it, to specifically indicate minimum radiation along the bisector of the angle?

A. Yes, sir, in accordance with Mr. Hogan's interpretation of the second Lindenblad patent.

X Q. 1715. You don't mean he suggested that he chose an angle to show minimum radiation along the bisector?

A. Well, I believe the statement was made that if these instructions were followed as to the angle, that predominant radiation would be along the axis of the antenna system, and no exception was made as to any angle or any hint that perhaps there would be an angle where there would be no radiation, or very little.

X Q. 1716. Again, may I ask: Were these angles chosen specifically to show minimum radiation along the bisector of the angle?

A. I had them worked out for me, and my understanding is that they were so chosen.

X Q. 1722. We also discussed the radiation diagrams of V's utilizing wires of eight wave lengths and seven and [fol. 477] three-quarters wave lengths. I asked you whether you had determined what the radiation diagrams of V antennas with the correct angle, according to Carter, would be for wires of eight and of seven and three-quarters wave lengths long, and you said, as I recollect it, that you did not know whether those diagrams had been prepared but you would find out. Could you find out whether they have been plotted?

A. Yes, I will be very glad to do that.

X Q. 1726. And furnish copies of them to me?

A. Yes, sir, I will do that.

Mr. Darby: Wait a minute, Mr. Blackmar, I will try to find that for you in a moment.

Mr. Blackmar: I want to know whether you plotted out radiation diagrams of a V antenna made with wires of these wave lengths, and with the angle as specified in Carter.

Mr. Darby: I do not think they have. These were plotted under my general supervision and direction to show specific

things, and I do not recall having instructed any plotting of that kind to be made.

X Q. 1727. One other thing I asked you to do is to determine the difference with respect to the third Carter patent, Fig. 12, between the curve shown there and what you consider to be the correct angle for a wire of a wave length between an integral number of half wave lengths, such as 6¾ or 7¾?

A. I feel pretty sure you did not ask me to give you that information, although we discussed that, and I told you I couldn't answer it offhand, and then we discussed afterwards, other exhibits showing radiation, the diagrams in the [fol. 478] two exhibits you have just referred to, for instance, given seven and three-quarter single wire and eight wave lengths single wire, and I said it was a matter of a degree, and I thought that was all you wanted to know.

X Q. 1728. Originally you stated it might be as much as five degrees?

A. No, sir, I said I couldn't remember, I gave you no values at all. The fact was, I couldn't remember.

X Q. 1730. Mr. Kelley, just one more subject in connection with the second Bethenod patent, No. 625,293, which is the one showing a slanting wire radiator. Assume this time the presence of an image; what is the direction of principal radiation from this antenna?

A. And also assuming a perfect ground, it will be in the horizontal direction, in other words, along the angle of the bisector between the wire and its image, that is, the wire BC and its image.

X Q. 1732. Supposing it is set up over actual ground, not perfect ground, as I understood you to say yesterday that perfect ground does not exist, is that correct?

A. That is correct, perfect ground does not exist. If that is set up over imperfect ground, the maximum radiation will be inclined to the horizontal.

X Q. 1733. In view of that statement, going back to Plaintiff's Exhibit 36 for Identification, would you be willing to sketch in, in the upper figure 4, on the sheet, and Fig. 5, the general nature of radiation in the principal direction?

A. Yes. I understand this is not for the purpose of drawing any quantitative conclusions?

X Q. 1734. That is correct.

A. And, if you will remember, yesterday I hesitated be- [fol. 479] cause I wanted to be absolutely sure about imper-

X Q. 1682. You mean "Yes, assuming they are?"

A. "Yes, assuming that they are."

X Q. 1683. Now will you please refer to the article in Q. S. T., the Melton article? What do you find in this article with respect to directivity?

A. The subject is not explicitly discussed in the article at all.

X Q. 1684. Does he anywhere show, disregarding the so-called image, the use of, or does he suggest the use of parallel wires as an antenna?

A. Assuming that I must disregard the image, he does not.

X Q. 1686. Or staggered wires or V wires?

A. The same answer applies.

[fol. 474] X Q. 1687. Now, you have referred to the book of Mills on Radio Communication, and particularly a formula or formulæ that appear on page 156. Could you determine from this formula the directive effect of the combination of two electrically long wires?

A. This formula would be a very necessary adjunct; one would have to do more than that, one would have to use Abraham, Bontch-Broojevitch, and what other information was available.

X Q. 1688. And that would be true whether you were referring to parallel long wires, or long wires in V formation, would it not?

A. Yes, sir, if you are now speaking of the matter of radiation patterns in all directions; nevertheless this is the nucleus of it. In other words, spacing and phasing are fundamental things to know as well as relative amplitude in any particular direction, and knowing those three things one can determine what the radiation is in that direction as compared with some other direction in which the same elements are also known.

X Q. 1697. Now will you please turn to Q. 523 (R. p. 376). In an answer relating to directivity of antenna systems you said "the first Lindenblad patent certainly if arranged as it was intended to be arranged so as to obtain the intended object,"—by that I presume is meant assuming the correct stagger and correct spacing?

A. Yes, assuming the corrections in the disclosure.

X Q. 1698. (Continuing reading)—"would be fully as directive as the third Carter patent," and of course you meant there the structure made under the third Carter patent?

A. Yes.

X Q. 1699. Do you agree that as compared, for example, to the standard di-pole as a standard, the power gain, as we [fol. 475] defined it yesterday, in the desired direction, would be greater with the V arrangement of wires than with the parallel arrangement of wires?

A. My recollection is there certainly would be very little difference; that is, it would depend largely on this definition.

X Q. 1700. Which definition?

A. That you advanced in regard to directivity.

X Q. 1701. Have you the definition in mind?

A. I think I know what you mean, and I would say that there would be very little difference, if any.

X Q. 1704. What does this diagram of Defendant's Exhibit G show with respect to the radiation of the two wires, combined radiation of the two wires in the direction which someone has marked "Axis of the Antenna"?

A. It shows four units in that direction.

X Q. 1705. In the direction vertical to that?

A. Four hundred.

X Q. 1707. In connection with Defendant's Exhibit BB you stated that that represented wave patterns illustrating exactly the same results as those of Exhibit G; you said, in answer to Q. 542 (R. p. 378): "In so far as direction of predominant radiation is concerned with an angle less than 45 degrees." What did you mean by exactly the same results as represented by Defendant's Exhibit G, "in so far as the direction of predominant radiation is concerned"?

A. I assumed by "exactly the same results" in my answer that the same principle was shown, namely, that predominant radiation would be elsewhere than predominantly along the axis of the conductor system.

X Q. 1710. What is the direction of predominant radiation in a system such as that shown in Defendant's Exhibit [fol. 476] BB?

A. It will be in a multiplicity of directions. You could hardly say then that it was predominantly in any direction, but it certainly is not predominantly along the axis.

X Q. 1711. Yes, but the actual predominant radiation, can you state in what direction that would be with respect to the bisector of the angle?

A. The largest part of the radiation will not be along the bisector of the angle.

fect ground, and I assured myself on that point, and I will give you now in a very general way what the general appearance would be.

X Q. 1735. When you say you were not sure as to imperfect ground, you meant you were not sure as to its effect?

A. No, sir, it was not that, it was as to quantitative values.

X Q. 1736. I am not asking for quantitative values in this case, only qualitative.

A. Yes. In the part of the sketch marked upper Fig. 4, I will extend the line for ground. And while I have not room on here, I am assuming that ground is not limited by the ends of the line showing ground. I mean to show the lobes in either direction to be the same or approximately the same. I think I have completed it, so far as you have asked me.

Mr. Blackmar: Now, this sketch states that the wire is four wave lengths long. I just want it understood that I am not by that indicating that I consider the wire in the Bethenod French patent as of any such length.

I offer the sketch that has been drawn by the witness on this Plaintiff's Exhibit 36 for Identification.

The Court: Very well.

X Q. 1746. Now, as I understood you, you have said, for example, in answer to X Q. 1404 (R. p. 436), that the differences of angle where they occur and the upward tilt of the beam of propagation due to the presence of the ground, are the only functional differences between defendant's antennas and antennas constructed as taught by the third Carter patent. Now, isn't it a fact, that aside from the dif- [fol. 480] ferences of angle between the sides of the V's found in some of the defendant's V antennas at Sayville, whose antennas are constructed as taught by the third Carter patent?

A. Assuming the functional differences?

X Q. 1747. Aside from the differences of angle where they exist?

A. Well, I do not so understand, and as you appreciate, I had nothing to do with the design of these antennas.

X Q. 1748. But I am speaking about their construction as it exists today, and not as to whether they were intended to be constructed in one way or another, but as they exist today.

A. As they exist today, I should say they are not constructed in accordance with the teachings of the third Carter patent.

X Q. 1749. Even aside from the question of angle between the wires?

A. Well, I do not see how I can leave that out of consideration because that is part of the teaching, or not

X Q. 1750. My question said, "Aside from that difference?"

A. Well, if you mean by your question, whether the antennas are generally V-shaped, in very general terms, yes, sir.

X Q. 1751. So far as the upward tilt of the beam is concerned that, I understand you have testified, is inescapable in an antenna constructed above the ground, is that correct?

A. It is true of any antenna.

X Q. 1753. And it is escapable, is it, in any antenna constructed above the ground, is that what you mean?

A. Well, it is inescapable, that is what the ground does to it.

X Q. 1754. Using wires, say, seven or eight wave lengths long, if you wish to retain the advantages of sharpness of [fol. 481] directivity made available by using proper angle between the wires and wish to get your beam tilted upward more than inevitably results from placing the horizontal V antenna over the ground, and wish to get, say, 20 or 25 degrees angle of tilt, as a matter of fact, is it not true that you could do so by tilting the plane of the V upwards as taught in the Carter patent?

A. The result would not be as good, and it would not be as good as one would not be making effective use of the ground, and it is just that point in connection with the third Carter patent, where the teaching is at fault.

X Q. 1755. If you wanted to get a beam of approximately 20 or 25 degrees from the ground, could you not do that by tilting the plane of the antenna as taught by the Carter patent?

A. I dare say you could.

X Q. 1756. Does any of the references to which you have referred herein show at a date prior to that of the application for the third Carter patent in suit any practical directive antenna system, comprising two or more wires, each of several wave lengths in length, which in its principle of operation makes any use of the relations which are expressed in, or may be derived from the Abraham formulas to which you have referred?

A. Yes, sir.

X Q. 1757. Which one?

A. The first Lindenblad patent, assuming correct instructions, does so.

X Q. 1758. Is there any other?

A. The second Lindenblad patent, assuming Mr. Hogan's interpretation of it, as a standing wave antenna, forming a V with the theoretical radiation along the bisector of the angle, along the axis of the conductor system, assuming all this, the second Lindenblad patent also.

[fol. 482] X Q. 1759. That is assuming that the correct angle is applied to it, is that what you mean?

A. Yes, sir.

X Q. 1760. Is there any other reference that meets the question that I have asked?

A. Takagishi using the two electrically long linear conductors, excited in phase opposition, if proper spacing with that phasing were used, would also be a reference of the type that you have asked for.

X Q. 1761. Any other?

A The French patent to Bethenod, No. 596,737, assuming again the proper spacing and phasing relations between the radiators.

X Q. 1764. Is there any suggestion in that patent as to use of the relations expressed in the Abraham formulas?

A. No, sir, I assume that was well known.

X Q. 1765. Have you completed the main question as to references that meet those specifications?

A. I think so, but if I may have a few more moments, I would like to make it complete. The British patent No. 14,449 to S. G. Brown.

X Q. 1767. You remember that one of the statements in the question was wires each of several wave lengths in length.

A. I am sorry. Well, then, although in my opinion, this is an anticipation, nevertheless, with that limitation, I can not very well include it.

X Q. 1768. Is there any other that you still wish to check?

A. That is all that I can think of at the moment.

Mr. Blackmar: That is all.

Redirect examination.

By Mr. Darby:

R. D. Q. 1769. You indicated, Mr. Kelley, that there was some comment you would like to make in connection with

[fol. 483] Plaintiff's Exhibit 36 for identification. Will you please make that comment now?

A. Yes, sir. I noticed when this was submitted to me that I was asked to draw the principal lobes of radiation in a general way for two classes of radiators, if I may put it that way, one where the wire and its image cooperate. the wire being inclined to the surface of the earth and its image likewise by nature also inclined; and the other class with two wires inclined to each other. I was asked to put these lobes in looking edge on to the V wire, that is, where the two wires are present, namely, in the direction where one wire covers the other wire as you look at it. In the other case where there is the inclined wire above the surface of the earth I was asked to put the lobes in looking at it from a plane perpendicular to that.

Referring to the upper Fig. 4, which is for the inclined wire with a perfect ground, had I been asked to draw the principal lobes looking down on the wire, in other words, making it comparable with the showing for the two wires which is given in the lower Fig. 2, then the diagrams would have been identical.

R. D. Q. 1770. Now, you were asked about tilting those wires of the third Carter patent in suit at an angle to the horizontal surface of the earth in connection with obtaining a desired angle of say around 25 degrees to the horizontal. My question is does the Carter patent teach expressly or impliedly anything about obtaining principal radiation at any angle to the plane of the wires?

A. No, nowhere in the third Carter patent is it taught to do anything but radiate in the plane of the wires.

[fol. 484] R. D. Q. 1771. Likewise you were asked about the two angles which the additive lobes of radiation make to the wire from which the lobes emanate in a V type of antenna, and in the example given, namely, 45 degrees, you stated, if I recall your testimony correctly, that one angle, that is, the angle made by one lobe, would be minus 22½ degrees, and the additive angle made by the other lobe would be a plus 22½ degrees in the example given. Was or was not your answer given in considering that type of antenna in free space?

A. It was given assuming the antenna to be in free space.

R. D. Q. 1772. I think you likewise referred in your cross-examination to the I. R. E. article by Carter, Hansell and Lindenblad, Plaintiff's Exhibit 20, with reference to dis-

closures therein of ground effect as a prior statement of Carter, that is, prior to the date of the Carter patent which has been marked in evidence as Defendant's Exhibit U. Will you please state what justification you have for referring to the statement in this article as a prior statement of Carter's?

A. I was speaking generally, and I had no justification for attributing that statement to Mr. Carter in view of the joint authorship of the paper.

R. D. Q. 1773. Likewise, with reference to your testimony on cross-examination concerning the differences between the functions and principles of operation of the third Carter patent in suit, No. 1,974,387, you testified that the ground effect and angle between the legs of the V, as I recall it, were the only differences between the functions and principles of operation of the antenna disclosed in the third Carter patent in suit and defendant's antennas. In giving [fol. 485] that answer did you have in mind the statement in the Carter patent on page 4, line 35, the paragraph beginning at that point?

A. Yes, sir, I did.

R. D. Q. 1774. If for any reason you considered the Carter patent to be confined in its disclosure to the use of a multiple of half wave lengths, would your answer have been the same?

A. No, sir, I would have added that there was also a difference as to the electrical length of the sides of the Vs, with the single exception of antenna No. 8, which is four wave lengths long.

R. D. Q. 1784. It was brought out on your cross-examination that in the comparitive charts which are in evidence as Defendant's Exhibits S and T, you assumed perfect ground. Have you had charted, for similar comparative purposes, the same effects at an angle of 45 degrees, at an angle of 50 degrees, as applied to antenna No. 8, with the worst possible ground?

A. I have had such diagrams calculated, and the character of the ground is much poorer than one would encounter in practice, and it shows the same relative effect. Namely, with the angle of 45 degrees the radiation resulting from the cooperation of the antenna and its image in the ground is greater; in the maximum direction, than had the angle 50 degrees been used, the angle 50 degrees being the angle

calculated from the Abraham formula and specified by Carter.

R. D. Q. 1786. What would you have to say as to actual condition of the ground in so far as its comparative effect is concerned, in the various instances?

A. In these two exhibits I think that point is clearly brought out, since we go all the way from perfect ground [fol. 486] to something which is poorer than anything one would be likely to encounter, and the same general effect is maintained.

Mr. Darby: I offer one of the charts in evidence showing the worst possible ground.

(Marked Defendant's Exhibit HH in evidence.)

R. D. Q. 1787. I see that you have made this chart or had it made only with respect to antenna No. 8.

A. Yes, sir.

R. D. Q. 1788. Would there be any difference in the comparative effects if it were worked out in connection with all the other antennæ of the defendant in actual use by defendant, and I am excluding antenna No. 2 as rebuilt?

A. Has the same general effect. By that I am assuming the effect of going from perfect ground to extremely poor ground, that whatever would hold for the perfect ground will also in general hold for the imperfect ground, relatively speaking. Of course, by that I do not mean any very precise relationship except the general effect would be the same.

R. D. Q. 1789. But the effect of the ground would be the same in both cases illustrated on the chart, wouldn't it?

A. Yes.

R. D. Q. 1791. And the chart is for comparative purposes?

A. The chart is for comparative purposes.

R. D. Q. 1792. Will you read into the record, please, the conditions of the ground assumed? I think you will find them on the back of the chart.

A. The diagram shown on this exhibit for defendant's antenna No. 8, at .49 lambda above ground, the ground [fol. 487] having a conductivity of one-tenth times ten to the minus 13 electromagnetic units and dielectric constant of 7. That is all.

Mr. Darby: Mr. Blackmar, you asked for the formula. I hand it to you. I would like to have the record show it has been supplied. That is all.

Recross-examination.

By Mr. Blackmar:

R. X Q. 1795. Mr. Kelley, it seems to me that the record may show the same thing with respect to this chart, Exhibit HH, that I pointed out yesterday—I think it was in connection with the prior similar exhibit. Did you mean, when you stated that what was shown on this chart applied also to all the other of defendant's V antennas with the exception of antenna No. 2 rebuilt, in respect of the difference in angle of maximum radiation over ground and with respect to the width of the beam over ground?

A. No, sir, with respect to the length of the lobes shown on the right-hand part of the diagram drawn in the maximum direction.

R. X Q. 1796. Did you mean that in each of defendant's antennas outside of No. 2 rebuilt there is a greater maximum length of the lobe in that direction than there would be using the Carter angle over the same ground?

A. Yes, sir, I haven't had them calculated, but the angles have been chosen so that such a result would be reasonable, and I am sure it would be checked on calculation.

R. X Q. 1800. Is it not true that in both the case of the single wire and of the V, that under the image theory there is an image in the ground of whatever is above it,—[fol. 488] of the entire antenna system?

A. That is entirely correct, sir.

R. X Q. 1801. So that in the case of the single wire above the ground the image is of one wire, is that correct?

A. Yes, sir.

R. X Q. 1802. And in the case of the two-wire V antenna the image in the ground is an image of two wires, is that correct?

A. Yes, sir; it can easily be visualized in terms of the optic nerve, it is what you see by reflection.

R. X Q. 1804. Where there is a horizontal V antenna of two wires, and we will assume that the bisector is in easterly and westerly direction and that the one wire is on the southerly side of the bisector making an angle of 22½ degrees with the bisector, and the other wire is on the northerly side of the bisector making an angle of 22½ degrees also with the bisector, will you tell me approximately the angle of principal radiation of the system with respect to the southerly wire in that case?

A. I would be glad to do so, but I don't recall having said anything about that in my redirect examination. All I referred to was what I assumed in respect to conditions, and that was that this was in free space, nothing more thar that.

R. X Q. 1805. I want to take you down now so we are assuming that the V is set up over ground as the defendant's antennas are set up.

A. There would be different angles, and I can't tell you offhand what they would be.

R. X Q. 1806. What would be the difference in angle of the beam of principal radiation with respect to one wire as compared to the angle with respect to the other wire in that case?

A. You mean considering this beam not in the plane of [fol. 489] the wires any more, but at some angle to the wires, it would form two different angles of the same magnitude, but on opposite sides of the direction of principal radiation.

R. X Q. 1807. That is, the angle of principal radiation in one case might, for example, be 30 degrees with respect to one wire, on one side of one wire, and it would still be 30 degrees with respect to the other wire, although on the other side of it, is that what you mean?

A. Yes, sir, on the other side of it.

Mr. Blackmar: That is all.

Mr. Darby: That is all, Mr. Kelley, thank you.

ROBERT MEADE SPRAGUE, called as a witness in behalf of the defendant, being first duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside at Sayville, Long Island. I am employed by Mackay Radio & Telegraph Company, and have been for approximately three years, in the capacity of Engineer throughout all that period of time. I am located in Sayville, at the Sayville plant. I am a part of the staff that has charge of the Sayville plant, the transmitting plant.

I am familiar with the circumstances under which antenna No. 2 was rebuilt. They were as follows: We received an order from our New York office on the morning of September 9, 1934, to dismantle the original No. 2 antenna, which [fol. 490] was being used on a frequency of 147.40, for Europe, and to erect an antenna for 'Frisco on the same poles that were already standing, turning this other antenna in the general direction of 'Frisco. This work was completed in one day and one night, and was put into operation the following morning. That antenna was operated approximately three months, intermittently.

To refresh my recollection I have consulted the official records of the company. The use of that antenna was discontinued in December of that same year, 1934. There has not been any use of it since that time. It is not in a condition for use.

ANDREW ALFORD, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness My full name is Andrew Alford. I reside in the City of New York, Manhattan. I am employed by the Mackay Radio & Telegraph Company as an engineer.

My technical education, in so far as higher mathematics are concerned, was as follows: After graduation at the University of California, I studied at the California Institute of Technology, and I was a Teaching Fellow at the Institute of Technology for about a year and a half, and Dr. Milliken was then the Chairman of the Executive Committee. One of the subjects I taught was advanced calculus, and another one was analytical mechanics.

[fol. 491] As to the nature of my employment as engineer with the Mackay Company, one of the things that comes under my jurisdiction is the design of antennas and various calculations connected with it. My jurisdiction is not confined to work of that character only as affecting United States work; I am quite frequently called in, practically always, as a matter of fact, whenever there is a question in connection with an antenna design in some other country

where the International Telephone and Telegraph Company or its subsidiaries might want to erect an antenna.

I personally drew these drawings on these two sheets, Defendant's Exhibit A,—traced them as a matter of fact. I traced those curves from photostats of curves found in the file wrapper of the Lindenblad patent, No. 1,927,522.

I personally checked charts which have been marked in evidence in this case, Defendant's Exhibits E, F, G, S, T, X, Y, Z, BB, CC, DD, FF, GG, HH. Some of them I calculated myself. I believe they are correct.

Cross-examination.

By Mr. Brown:

The Witness: I have been with the Mackay Company about two years.

X Q. 18. And how long have you been working on the preparation of this case?

A. Well, I don't know just what——

X Q. 19. Most of the two years, haven't you?

A. No, I don't believe so.

X Q. 20. How long did it take you to make these calculations?

A. Well, some of these calculations, of course, were made a long time ago.

X Q. 21. By you?

A. Some of them by me, yes.

[fol. 492] X Q. 22. What do you mean by "a long time ago", two years?

A. I don't exactly remember.

The Witness: There were a number of mathematicians working under my immediate supervision, however. I had several young engineers helping me to make these calculations, graphs, and so forth.

I am quite sure that all of these calculations and graphs put in here are correct, even though I had other mathematicians help me, because I checked them with as much care as one possibly can use.

As to whether I know anything about antennas practically, I have adjusted antennas, I have designed them, and I have tested them.

The graphs I have produced here and identified are not mathematical analyses pure and simple, so far as I am

concerned. I may add this, that a calculation of this sort gives you an answer to a practical problem with a considerable degree of accuracy.

Redirect examination.

By Mr. Darby:

The Witness: I either personally calculated or checked the calculations from which the models, Defendant's Exhibits O and P, were made.

Edmond Bruce, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Mr. Darby: The notice under which the testimony of this witness is offered reads:

"In connection with the above suit, I hasten to give you the necessary data in connection with the additional items [fol. 493] of defense that will be used at the trial as soon as the information thereof was uncovered and made known to me.

"As to the two Lindenblad patents and the third Carter patent (of the Supplemental Bill), prior invention, prior knowledge, and prior use of Edmund Bruce and/or Bell Telephone Laboratories of and at New Jersey."

Direct examination.

By Mr. Darby:

The Witness: At the present time, I live at Red Bank, New Jersey. I am a research engineer for the Bell Telephone Laboratories.

My technical education was as follows: I was a technician in the United States Navy, from 1917 to 1919. Following that, I spent a year at George Washington University. Following that, I had four years at the Massachusetts Institute of Technology, where I graduated with the degree of Bachelor of Science in Electrical Communications.

In the fall of 1924, I went into the engineering department of the Western Electric Company, which later was reorganized into the Bell Telephone Laboratories. Throughout that period of time I have been research engineer. My

particular efforts have been in the direction of short wave radio communication.

While there, I believe I devised what may be termed a rhombic antenna. I consider myself to be the inventor of that type of antenna.

As to the circumstances under which I made that invention: Excluding the work that is not material—assuming that you are interested in antenna developments—I will [fol. 494] begin there. I was first interested in what was required to improve short wave communication.

I appreciated, after experiment, that to overcome the inherent noise in receivers, it was necessary to get more energy output from the antenna systems—that was my first object.

My second object was to develop directive antennas, and in so doing, it was hoped to improve the ratio between the signal received and the extraneous static and other interferences.

The third object in the work was to develop a means which satisfied these preceding two mentioned objects, in a manner that was as cheap as possible.

I think those are the three principal objects of this work.

In order to find prior art among others, I was interested in the development of the prevailing theories on the so-called wave antenna, which is the use of long waves, prior to my time, of working on this problem.

In reading that material, I was taught that a wave antenna was a long wire extending in the direction of the distant transmitter, substantially horizontal, and that the antenna relied on the so-called wave tilt for its operation and had not this wave tilt been present, the antenna would not be very useful.

It is known in the art, and I have checked with my own experiments, that there exists a surface wave—by that I mean a wave traveling over the ground, and that is what we call imperfect, and I mean by imperfect, that the dielectric constant and conductivity are both lower than the extreme optimum values, and the surface wave in traveling over such earth is retracted at the foot, producing a wave tilt.

[fol. 495] I was taught by what I read regarding wave antenna operation that it was this wave tilt which produced the useful component in wave antennas.

Having this knowledge in mind, I proceeded to some of my earlier experiments.

I have in my hand here a photostat of an original record in my own handwriting which I made on May 13, 1926.

The second sentence is of importance:

"The following antenna comparisons with a loop were made."

I shall explain that. In order to determine whether an increase in energy was obtained we wished some fixed standard of comparison, and as we made various experiments we would refer back to that standard, and in that way we could measure the degree of improvement.

The layout of the sytem, I find under the heading:

"Entire tests of distant oscillator output constant," meaning by that that there were no corrections to be made for changes in oscillator output to a frequency, say, of 12.2 times 106 cycles per second, approximately.

On this paper I have a series of columns. On the left-hand side are the series of antenna arrangements used. It starts with a small loop antenna, to which I referred before, which is a reference for all these comparisons.

There are three other columns on the right-hand side of the paper. The two columns on the extreme right refer to the amount of inductance and the amount of tuning capacity that were used in the particular experiments. The only reason that is for is to show that the proper point in [fol. 496] which resonance was obtained, and also the attempt to match impedances, which is also known in the art, that in connecting two pieces of electrical apparatus together, it is desirable to match the impedance.

The important column there is the one just to the right of the figures, which reads: "Attenuation for constant output." I might say that this requires explanation.

I have partaken in the development of measuring apparatus whereby the essential scheme is that a deflecting meter on the output is always kept to a constant deflection on all signals with the means, in that apparatus, whereby, where the application ratio can be changed in known amounts.

The column listed here is intended to convey the idea of voltage ratios that were in a resistant attenuator, which lowered the gain of the set.

One can judge the result by the magnitude of these figures since the output was constant. The judgment is to be made by comparison of these numbers, the higher number representing the greater output attained.

Now, as comparing the various sets of antennæ involved, in the comparison loop antenna, which is indicated here as being a two turn loop, it makes no difference what size this was, so long as the same standard of comparison was used throughout, the attenuation was set for a ratio of 10.

In relation with my reading on the operation of wave antenna, I constructed the system which is indicated just below that, to constitute a receiver, constituted of a wire that was substantially horizontal and that wire was .125 wave lengths in length, from the same receiver diverging from nearly the same point.

[fol. 497] There existed a second wire besides this one I mentioned as being substantially horizontal, a second wire of the same length and diverging from closely to the same point at the receiver up to a separation of the far end of .112 wave lengths.

Under tests with that, as mentioned previously, with the distant oscillator at a constant output, and with the test receiver with a fixed gain and fixed output, the attenuator now read 75.

And the further columns indicate the inductance and capacity that was used for tuning that.

Confining our attention to the attenuation of 75, that means that where the ratio of signal thrown away was now 75 times, in the previous case, it was ten times, therefore, this is, in voltage ratio, 7.5 as good as the loop that was used as a standard of comparison.

Now, proceeding to another test which is indicated directly below that, here the wires are in the same general form, except the wires are increased in length. The length of each element is now .25 wave lengths, the spacing at the far end is the same as before.

The idea of this test being what effect it had when we increased the length of the wire, other conditions being constant.

By the attenuator setting we see the column of 68, which is, as we compare that with the 75, a result which was not quite as beneficial as the preceding one.

Proceeding to the next diagram below that, here we have the same length of wires as discussed just above.

The only change that was intended in the layout was that the far end, where previously it had been .112 wave lengths in spacing, is now .25 wave lengths in spacing.

[fol. 498] There are several numerals indicated here, the difference between those numerals being this: that the inductance seen at the center column, one, two, three and four turns, and the right hand column indicate the difference in the capacity of condenser which indicates resonance.

What is intended to show there is that an attempt was made to match impedance between the antenna and the receiver proper, and we selected for comparison the optimum result obtained there and, as I look through, I see that 95 is the larger of the attenuator settings. Therefore, as all other conditions were intended to be either the same as in preceding experiments, we now compare the 95 with the preceding figures of 68, 75 and 10, which, of course, it exceeds, therefore, this is the better arrangement than any of the previous ones tested.

We note that the difference between this and the test immediately above is that there is just a greater divergence of wires at the far end. The difference between this one and the system, which is the two by four, the one under discussion, is that the wire is longer and the spacing is greater. So far this is the best arrangement discussed.

In an attempt to be logical, proceeding further in the tests in orderly steps, we now used the same general arrangement, but the length of the wires now is .5 wave lengths long, the spacing is the same as used, the spacing at the far end is the same as used in the preceding tests. Again looking at the column for attenuation I see figures of 70 and 58 obtained under various conditions of conductance, impedance matching, and so forth. I think both of these are inferior to the 95 previously mentioned. Therefore this is [fol. 499] evidently not as good as the preceding case, in spite of the greater wire length.

As a further experiment, the same arrangement was used except at the far end, instead of being .25 wave length spacing between the ends it is now .375. Here I see that the attenuation, other things being equal, is recorded as 75 and 62. Here again 75 does not appear to be as good as the 95 that I mentioned above.

This record is in my handwriting. I made it on May 13, 1926; it is dated at the top of the page. I had the original record in a notebook in my possession. It has been con-

tinually in my possession from that time except such times as it has been in the hands of an attorney. This record is a record of what I have done; also the first arrangement here is I consider an outline of what I intended to do. The physical work I did at this time by myself.

On May 14th, the following day to the one just discussed, the experiments were continued. From day to day we can't necessarily expect the gain of a receiver, of an oscillator output, to remain the same. As we do not necessarily expect that, a test was made to see that it did, and I see that for the very same set of conditions on the loop that the attenuation constant was again 10. Therefore, the attenuations that I read are directly comparable to the previous page.

I see here a notation which hasn't been indicated on the preceding drawing, that the distant oscillator on which these tests were made is indicated here as being four wave lengths away. Evidently it was the same thing the preceding day. I am judging that now because I produce the same results, using the loop antenna.

[fol. 500] Proceeding with the experiments, we got a certain encouragement increasing the length of the wires, and it is quite obvious that for any given length of wire there is some divergence, or in other words, some spacing at the far end that appeared to go with that length of the wire. That is the teaching in the experiments so far.

So the next step was to take a comparatively long wire and see what the results would be. These tests were conducted in the same manner as before, but now our wires are 2.25 wave lengths long, and the far end spacing is .375 wave lengths long. I believe that was the limit that was possible on the comparatively small pole that was used at the time. The setting for the attenuator here was 150 for two sets of readings, evidently two methods of tuning give approximately the same impedance match, and therefore got much the same effects. But the important point is that the 150 is in excess of any other attenuator setting that I have mentioned, therefore this is a better arrangement. All of which indicates that as I increased the length of the wire I got an improved result.

I evidently did not further attempt to increase the spacing at the end of the wire on account of the restriction of the poles that I had available.

There is one thing that I want to be certain of, though; as I made the wire considerably longer in this experiment than the preceding experiments I found that the far end of the antenna was getting rather close to the test oscillator which is indicated here as four wave lengths away compared to the length of the wire, 2.25 wave lengths. In order to get a further check of what the results would be had the oscillator been further away, I have drawn in the [fol. 501] third test indicating that the conditions are the same as previously, except that the oscillator is moved four wave lengths from the far end of the antenna rather than four wave lengths from the receiver. I see here that the attenuator setting for this condition was 48.

The importance of these two tests will be seen in what I have to say which follows:

I mentioned previously that one object in my work in antennas was to get more energy output from the antenna, which I believe indicated that by a proper length and angle here one might achieve such a thing.

A further object which I have previously stated was to get directivity in an attempt to reduce static and other interference. In order to test that, the oscillator was moved in stages around the antenna in a horizontal plane, and that is what I intended to indicate on the figure on the lower part of the page. That figure is intended to be a top view of the directional characteristics as written. If you will look at the various conditions, there are circles here with crosses in them. Those just merely indicate the position at which the test oscillator was placed for the tests involved. For example, there is a circle near the end of the top view of the antenna where it says alpha equals 150. Incidentally, alpha in this work was my symbol for the attenuator setting.

It appears quite dim in my photostat, but there is drawn here a vector which was intended to show that three of these spacings were all spaced four wave lengths from the receiver, one in front, one behind, and one alongside, all viewed from the top. The one in front, we say that alpha [fol. 502] equals 150, which I would like to point out is mentioned above as being 150 in the second test involved.

Those are the same conditions. That 150 can be compared with the backward direction. The oscillator was placed in back and I have it that that indicated at 38, so if

this is a fair set of conditions of directivity, in a forward direction my attenuator was 150 and backward 38, and the ratio between those two indicates the tendency toward unidirectional characteristic.

However, as I mentioned before, as this oscillator is getting fairly close to the far end I wanted the test condition to be perfectly fair, so I have taken another condition.

I moved the oscillator so that it is four wave lengths from the far end instead of four wave lengths from the receiver and I also noted that the backward position of the oscillator is four wave lengths from the receiver; in other words, an equal distance from the extremities. As we compare them under these conditions we find them to be 48 as against 38 in back, which indicates there was nothing improper in the experiment in relation to the addition of the oscillator.

Again, as 48 is larger than 38, this system tends toward unidirectional characteristic.

So much for the forward and backward direction.

Now for the sideways direction, the oscillators were placed both four wave lengths in broadside direction, or, I should say, perpendicular to the plane of the wire, and perpendicular to the plane to the ground through this wire. There was placed four wave lengths beside the receiver and also four wave lengths beside the extremity of the [fol. 503] antenna. At four wave lengths beside the receiver the attenuation was 10.5, which is considerably less than any other value that I mentioned.

Also, when the oscillator was placed four wave lengths beside the far end of the antenna, the attenuation was 8, which is still a small number compared with 48.50 or 38, indicating that the radiation sideways of this system was small compared particularly with the forward direction and also with the small backward directions.

I see I have written in the bottom of the page here, May 15, 1926, and the following day I went to New York to make an application for a passport.

At this stage of the work I was given work that does not pertain to this, and which called for a trip to England, and I think in the following month I left for England. I was temporarily putting aside this work until my return. Here is a sheet which I have dated on the top May 14, 1926, and the second paragraph reads: "It is definitely decided that I will sail for England with Southworth and

Hubbard about May 27th. Telephone to see what is necessary to get passports. Wilson recommends that I do this tomorrow." Southworth and Hubbard were fellow employees. I went to England as planned. To the best of my recollection, but I would say I was away possibly a month.

These two pages dated May 14th are both entirely in my handwriting. They were made on the dates indicated at the tops of the pages which I have mentioned in their description. The entry at the bottom of one of the pages was made on May 15, 1926.

[fol. 504] I disclosed this work that I had been doing; I mentioned reading material pertaining to the operation of the wave antenna, so-called wave antenna, used in long waves. I obtained this material from memoranda and clippings from publications which were in the possession of Mr. Englund, one of my associates in the Bell Telephone Laboratories. During the process of these tests, if my recollection is correct, on May 14th, I described to him the tests which I had undertaken. It is my understanding that in his personal notebook he wrote down a sketch of the layout and the dimensions of one of the arrangements I have discussed. I have seen it at a later date.

The Court: You saw at a later date something he purported to have put down at an earlier date. You don't know that he put it down on the date that he said he did?

The Witness: I don't know that he did it on the date he said.

The Court: No, but you saw something at a later date which he purported to have put in his book at an earlier date?

The Witness: Certainly.

The Witness: On returning from a trip to England, and clearing up other matters following that visit, I again took up the subject. It seemed to me that the experiments indicated that for various lengths of wire there was an angle which gave an optimum result. I wished to, in my own mind, decide on the theoretical reason for that. On September 28, 1926, I have a record of what I thought was a plausible reason for the effects I had achieved. I have here [fol. 505] a plot of various lengths of wire, each wire laid out at an angle in relation to an assumed wave direction which is drawn here, which seemed to me a reasonable ex-

planation of why there is an optimum angle for each length of wire. It is also intended to indicate that there is a possibility that the longer the wire the more output I could expect from the receiver which was indicated in the experiment at least as a trend because the longest length of wire was the highest attenuator setting that I mentioned.

This is laid out on this spacing. Starting with No. 2 vertical wire, and gradually increasing its length, each time the length is increased, there is a rematching of impedance to the receiver—one continuously gets an increase in output up to the point of a half wave length. Beyond this point, by a small amount, why, the energy again decreases.

I have indicated on the right here a vertical line whose lower extremity is at zero and its upper extremity at .50, indicating half a wave length in length, and the wire vertical.

Analyzing the effect in such a wire, it appeared to me that voltage induced in the very far end had to travel down that length of wire to reach the receiver, and as the wire is half a wave length long, it is a half a period out of phase. This, of course, is an approximation. It is reasonably close, however.

Now, if we make that wire longer, the reason that we achieve the reduction of output is because it is beyond the half wave length. I might further explain this: that half wave length can be represented by a series of vectors tracing a semi-circle, and the resultant series of vectors tracing a semi-circle is a diameter.

[fol. 506] Now, should one extend the circle by a small amount, the points connecting the start and finish is less than the diameter. If you continue that far enough, the circle closes, and there is no resultant. Therefore, the maximum amplitude is substantially a half wave length.

Now, I am trying to convey on this paper, from this point on, that the far end of the antenna should be a half period out of phase in respect to the receiver, as the lower end of the antenna is at zero.

Now, if we make the wire longer and less energy, that is a disadvantage, but it seemed to me that I could advance the upper part of the wire into the wave direction, thereby getting an earlier sample of the wave, so to speak, and alter the phase relation such that I could still achieve the rule of having the far end of the wire have a period out of phase with the one end of the wire.

I have drawn on this paper a series of wires which follows that layout.

For example, one of the longer wires has indicated on its extremity one and a half, which indicates one and a half wave lengths. We drop a perpendicular down on the ground, which, incidentally, in this case, is assumed to be the wave direction, and we find that its distance from point O is one wave length. The projection on the wave direction as indicated is one half wave length less than the wire length. And that rule has been followed out in plotting all these various lengths of wires.

Mr. Darby: Mr. Blackmar wants to mark for identification the formula that we supplied him. I have offered to offer it in evidence instead as a defendant's exhibit.
[fol. 507] The Court: All right.

(Marked Defendant's Exhibit II in evidence.)

The Witness: On the exhibit of September 28, 1926, I had completed my description with the exception of a notation that I have in the lower right-hand corner, which says:

"Witnessed copy in possession of J. H. Couzens, Patent Department."

To the best of my knowledge I discussed this with Mr. Couzens a few days after September 28, 1926.

Mr. Couzens is an employee of the company; he is in the Patent Division. To the best of my recollection I discussed this on October 9, 1926, with Mr. Couzens. I have no knowledge of what became of the original witnessed copy referred to in the copy now in my possession; that would have to be obtained from Mr. Couzens.

The Court: Did you keep it or give it to Mr. Couzens, or what did you do with it?

The Witness: Mr. Couzens took it with him.

Q. 45. On this sketch it is annotated that the ground is shown in the conventional character of lines as well as the word "ground." Will you state whether or not in making that sketch you considered actual ground or perfect ground?

A. In a sketch of this type the important thing is the relation of the wire with the direction of the wave. How-

ever, perfect ground is intended in this case to fit that assumption.

Mr. Darby: I offer in evidence a photostatic copy of the [fol. 508] chart just described by the witness.

(Marked Defendant's Exhibit JJ in evidence.)

The Witness: The next sheet I have before me reads at the top "Daily wire measurements at Deal on 14 meters, July 19 to 21, 1927, small transmitter at a distance measuring set No. 6." As indicated by that sentence, a small transmitter was placed at a distance; there was a tall pole available at Deal, so that the wire could be suspended; running from a pulley at the top of that pole was a rope, and I am explaining that, in that various lengths of wire were used in this experiment, but in all cases slack was pulled out by means of the rope.

The diagram in the center of the page indicates the distant transmitter by the box marked T. The receiver is in a box marked R on the right. The pole is indicated there. The solid line indicates the position of the wire. There is a dotted line on the other side just merely to indicate, as marked below, that I have referred to, as distance either toward the transmitter or away from the transmitter measured from the base of the pole as either plus D or minus D. I believe that notation appears in the data.

Going to the numerals written above this sketch, the first column is "Antenna length." I mean by this that this test was performed at the constant wave length of 14 meters as indicated on the top. We put up one length of wire, tested it, tore that down, and we put up another length and went through successive tests in that fashion.

[fol. 509] The next column labeled "Output deflection" shows 100, which is intended to represent microamps in all cases.

The next column is labeled "T. U." We have this in order here to explain that this differs slightly from previous testimony, in that there I had expressed it in voltage ratios. It is standard in communication work to express voltage ratios as, in those days, transmission units. Today we call it decibel and there is very little difference. "T. U." means "transmission unit", and it represents the ratio just to give a general idea of what is intended. One DB variation means a ratio between two numbers which differ by only approxi-

mately ten per cent. I am just saying this to illustrate the magnitude of the DB and of the TU is roughly the same thing. They were called transmission units at that time.

Again as before, the degree of the number represents the indication of what output was obtained at the receiver. There is no difference in that. We are just using the T. U. which is at a logarithmic arrangement rather than the previous ratio mentioned.

The next column is "Optimum Coupling". Here the notation is the same that I explained previously, the denominator indicates the number of turns in the inductance coil while the enumerator indicates the number of turns from the ground position at which the tap was used.

In all cases, the various tapping positions were used, and were always tuned to resonance. This is with the view to match impedances between the antenna and the receiver, something which is always necessary or the results do not mean a great deal.

[fol. 510] The next column is entitled "Horizontal Distance of Tilt."

There are several figures mentioned. All except the last and the first one are indicated in the minus directions, which, when we look at the diagram means that D indicates the direction from the foot of the pole, removed from the distant strength transmitter.

The final column is labeled "T. U. Improvement."

The nature of the unit T. U. is such that where previously our ratios were either multiplied or divided with each other as T. U. is logarithmic, a logarithmic relation, we are permitted to add and subtract them, and it makes T. U. a very convenient unit.

Therefore, for example, the first item in the last column is a dash which I will explain. The next one is 2.1. It is intended that 2.1 will be the difference between the two readings under the column labeled "T. U." about the center of the page; and so forth.

Without going into too much detail regarding this, we see a progressive increase in the length of the wire. In each case, the increase at which the wire inclined to the wave direction was altered by varying the dimension D, which is the distance from the foot of the pole; in all cases, regardless of the length of the wire, the slack was taken up by means of the rope structure, so that the wire was always taut.

If we now take the length of wire which is represented in the left-hand column and the column of T. U., we get the substance of the experiment; I will explain, as these columns are mentioned.

[fol. 511] Starting with the half wave length, lambda over 2, which is the indication for half wave lengths, the position of the attenuator on the receiver is 8.8. Now, all conditions are supposed to be altered where you get the optimum for that length of wire, I mean the angle of tilt, the matching of impedance and tuning and so forth. By going to the one wave length wire, we see 11.9, again, everything was done to get the optimum result. And we see that that is slightly better than the half wave length wire, so we get a better result by changing the length of the wire and readjusting the tilt angle.

Following that, we have a wire length of two wave lengths, and the result is 17.5, that is again better. Then, at four wave lengths, the result is 20.5. In other words, provided that in each case we select the proper angle and did the various other things which anyone skilled in the art would do to optimize the result, we find a progressive increase in the output of the receiver as the antenna length is increased.

I see down in the last item in these columns a similar notation of four wave lengths, but on the column labelled at the head, "Horizontal distance of tilt," it says: "Plus, less than 150 feet." What is meant by that is, we went on the other side of the pole. There was a suspicion that there might be a bi-directional characteristic to that sort of thing, or due to reasons which we appreciated at that time, such as attenuation along the wire, there may be a tendency toward the uni-directional characteristics, and that is what this test was intended to indicate. We see, when we put the receiver on the side towards the transmitter, the T. U. [fol. 512] drops from 20.5 to 18, and that indicated clearly that in spite of moving the receiver closer to the oscillator, the conditions of the experiment were such that we got less energy where one would expect more energy under those conditions. But that was due to the tendency toward unidirectivity in the wire under test.

So this expression shows us that is really an attempt to check what I have stated previously as a conception of length of wire and tilt of that wire, to go with it. The tilt is

measured between the wire in the direction away from propagation.

All the entries on that page are in my handwriting. They were made certainly at or before the latest date indicated above, which says July 19th to 21st, but I am certain that it is either July 21, 1927, or prior to that.

In the various antennas that I used and concerning which I have thus far testified, the antennas were open ended. The antennas on my note of May 13th were open ended. And my antennas on my note of May 14th, were open ended.

Referring to my diagram which is in evidence as Defendant's Exhibit JJ, all of the entries on that are in my handwriting, other than the stamp up here which evidently was put on here by somebody else. I made that record on the date indicated above which says September 28, 1926.

Q. 57. Now, I hand you a sheet of paper, and I ask you whether or not you recognize any one or more of the mathematical formulæ thereon written, and whether or not you ever checked the work represented on this Defendant's Exhibit JJ, with any one or more of those formulas.

A. In a quest of this type, I, of course, do not memorize these formulas. I, however, do recognize the general form of them.

[fol. 513] You have certain symbols in here which I can only assume their meaning, but I understand the third formula here—it may be that I am accustomed to using complementary angles to the ones expressed here.

I appreciate when that is done one can interchange sines and cosines, and it is perfectly permissible. If someone can say that this is an accurate formula, I recognize the general form.

May I refer to my note book to refresh my memory?

A formula of the general form which I believe is under discussion was noticed by me in an article in the Institute of Radio Engineers. The article is by Levin and Young. The sheets I have here, I am searching for the date of publication, which I don't see. However, it says in a footnote below, "Received by the editor January 13, 1926." Whenever that was published, I judge in 1926, I saw the article shortly afterwards, and attempted to digest, and I believe that I saw in that article an equation that is of the general form you have here. Incidentally, this is not an

equation. It seems to be one term, there is no equality sign, and so forth.

Q. 62. Which one or ones of the sheets that I handed you does the formula mathematically resemble the formula that you saw in that article?

A. I find a formula on page 7 of this publication, labeled "Formula 15." I see by the notation above, it says, "Section D grounded antenna." The final term of this looks very similar to the one you have written on the paper here. I will read it:

"Cosine (Beta cosine theta)."

[fol. 514] That is all in the numerator. In the denominator, there is "Sine theta."

The principal difference I see between these two is they have used the term beta, and the formula that you have handed me uses in its place pi N over 2.

Looking elsewhere in this publication, on the bottom of page 6, they define beta as pi over 2 times N, which, I believe is the same thing with the exception that you have got a subscript to that, sub zero, where it is here just theta, and I imagine it is a similar reference.

Mr. Darby: I will offer the sheet in evidence.

(Marked Defendant's Exhibit KK in evidence.)

It is my understanding that the formula under discussion was derived under conditions of a wire being vertical, erected over perfect ground. The wires which I had made tests were inclined at an angle over the ground which was not perfect. I am not inclined to believe that this formula fully explains the results which I have seen.

The next record I have before me is written in my handwriting, with the exception of a witnessed signature on the bottom. It is dated August 2, 1937. I will read:

"Using one of the long tilted wires as an element"—may I pause to explain in this testimony that there is a vast amount of work in between the various instances that I have discussed here and the subject of tilted wires has been [fol. 515] thoroughly investigated by experiment and calculation, and with that known, this evidently is the next step in the conception.

I will read again, "Using one of the long tilted wires as an element it is desirable to find methods of using them in

arrays. Economy demands first studying the combinations which require only one supporting pole.

"The simplest scheme is shown below."

Below that is a sketch.

In the sketch we have indicated ground with a pole which is upright. To the right of that pole is what I have been terming a tilted wire, the same general form as previously discussed.

On the left hand, opposite the pole, there are dotted lines. What I intended by this sketch is to indicate that a second line should be added to the first element and getting a cumulative relation between the two.

There is a vector diagram below the sketch which refers to the center point of each wire and to those skilled in the art explains the cumulative relation. Under the condition of the direction a wave assumed, the length of the wires and their disposition as to angle, these vectors indicate that the two elements are cumulative in their result at the receiver.

I read further down the bottom, "It is seen that the tilts of each element are maintained the same as if they were alone. It is also seen that with the above arrangement no radiation can take place in the YZ plane."

By YZ plane is meant a co-ordinate system where the X dimension lies in the plane of the paper and horizontal, the [fol. 516] Y dimension lies in the plane of the paper and is vertical, the Z dimension is perpendicular to the plane of the paper; therefore the YZ plane is that plane which is perpendicular to the paper in passing through the fold. There is a notation here, which has been added since the original record was made. I refer to that in the middle of the page, which has my initials, and the date of 8/8/29. I will read the note. It says, "More vector points along the wire are necessary to show this last case". That note was added when going over all my previous work I was preparing a publication and while I found these vector relations are correct, to be convincing, why additional vectors should be added to make it prove convincing.

On the bottom of the paper I see it is signed with my signature on 8/2/27. In the left-hand lower corner I see the signature of Mr. H. T. Friis also on 8/2/27.

With my recollection refreshed by what I find on this paper I can state that I disclosed the subject matter to Mr. Friis on that day.

Q. 68. With reference to this page dated August 2, 1927, is everything on that page in your handwriting with the exception of Mr. Friis' signature and the date, that is, the date over Mr. Friis' signature?

A. That is true; with this exception. I see in the upper right-hand corner it says, "Exhibit D", which I did not write. Also under the diagram I see a dimension which, while dull, appears to be, "lambda over 2 between the pole and the receiver". I did not write that. Other than that, I believe everything is in my handwriting with the exception of Mr. Friis' signature. I do not know who wrote lambda over 2 under that diagram.

[fol. 517] The next record I have is dated August 9, 1927. It is evidently an attempt to confirm the conception which has been just described. I see by the sketch at the top, just for purposes of variety, we are no longer connecting the receiver to the antenna, but this time we had it connected to the transmitter, and the receiver was placed at a distant point. It is recognized by those skilled in the art by a theorem which we call reciprocity that the behavior should be the same if the transmitter and receiver are interchanged. In order to get this directly into an experiment I chose to interchange that in this particular case.

Also I see another variation from previous modes of testing in that where previously we had used a fixed wave length and varied the dimensions of the antenna, I have chosen here to use fixed dimensions of the antenna and vary the wave length. There should be, if this is properly constructed, there should be in the range the same behavior as I had hoped for in the conception previously discussed.

On the top I see that it reads 42.9 meters equals 141 feet. There is a similar label written directly above the wires of the sketch, meaning to indicate the length of wires.

I see here also in the upper left hand corner phi equals 58 degrees. Phi is indicated in the drawing as being the angle measured between the wire and the pole.

Referring to the various columns under the sketch, the left hand column reads "Transmitting condenser."

There is a series of numerals of equal increment which just merely mean that we progressively changed the wave [fol. 518] length of the transmitter. For convenience, the antenna current was recorded. Should this antenna current vary at all, why, a correction should be applied to the results. In general, the variations, with one or two exceptions, are not great.

There is another column labeled: "Receiver condenser" and that is for the operator's convenience and is of no interest here.

The next column is "Wave length." That is important, and I will refer to it.

By this change in the transmitter condenser we have changed the wave length, as indicated in this column.

Now, there is a column marked "Deflection". Here, for instance, on the top of that column, it reads 52 minus 33 equals 19. What was intended by that is the effect the receiver had on the output and deflecting meter, in which there was the initial deflection when there is no energy being received. In each case the initial deflection was subtracted from the total deflection which resulted, and therefore there is no need of paying attention to the figures except to those to the right of the equality sign.

As I go down and examine the numerals to the right of the equality sign I see variations until I reach one that reads 131. That, I believe, is the largest deflection there. To the right of that I notice the word "optimum".

Going to the right hand column it says "Wire length and wave lengths." Naturally knowing the wave length which is the subject of one of these columns and the length of the wire element as measured in meters, I should say that this wave length was measured in meters, then the wire [fol. 519] element was measured in meters, and one can obtain the wire length in wave lengths, and it was supposed to be the subject of the column to the extreme right.

And for the one that is recorded as optimum, I see that the wire length of each element was 2.28. Therefore, by experiment, we found an optimum condition under the conditions of the experiment.

Further down on the sheet there is indicated a test of directivity, as in previous measurements we were concerned with getting not only the largest output to overcome the residual noise in the receivers, and when I say "receivers"

it makes no difference whether the antenna is connected to the transmitter or receiver.

And another object which I have previously mentioned was to obtain directivity to discriminate against static. This lower test is intended to measure the degree of directivity that was obtained—I hope directivity will be taken as a general term—in an attempt to measure variations in different directions at a constant radius.

Here I have chosen to measure the distance of the receiver from the pole of the transmitting antenna at 60 paces away, a pace being approximately three feet.

This is intended to be a diagram looking down from the top, or a plan view. The oscillator is moved from point to point. As indicated, where the figure reads 121 for the deflection, the receiver was directly in front of the antenna.

Going down, at right angles to that, I see a dot which is supposed to indicate the position of the receiver and marked a deflection of only one, which is very much smaller, indicating that there was considerable degree of directivity. [Vol. 520] There is very little sent sideways, which proves my contention expressed previously when discussing all of these two 1927 exhibits, that no radiation can take place in the YZ plane. I think that this checks that contention.

There are intermediate points between those two with varying deflections, all of which are less than 121.

This test appeared to me to check that I was achieving in directivity what I had hoped for under the conception.

There is one other point here regarding the node at the bottom. I will read: "Note theoretical phi for optimum L equals 2.28 is phi equal 51 degrees."

Taking that 51 degrees and comparing that with the 58 degrees mentioned as the angle at which the structure was laid out, the 58 degrees being in the upper right-hand corner, there is a discrepancy of seven degrees.

I would like to point out that in all such experiments, there are several factors which I have called in my work "Correction factors", to the main principle under which things operate. I have previously explained that when one works with a local oscillator in the vicinity of your receiving equipment, you have to deal with what has been called a surface wave, in which there is a wave tilt or the foot of the wave next to the ground lags. Now, if one could assume

that such a lag was seven degrees in this case, we would get a perfect check of the angle theoretically.

I do not pretend for a minute to say that that is the only factor involved here, because there are a number of factors [fol. 521] in such a test which affect the accuracy of an angle. I might mention for one, attenuation along the wire might be involved, the influence of the ground on the system may be involved. But all in all, I consider this a substantially good check on the conception which has been previously discussed.

Mr. Darby: It has been called to my attention, if the Court please, that due to the fact that this subject matter is involved in some Patent Office proceedings, the witness has been referring, much to my surprise, to entries which do not appear on the photostatic copies that I have in my possession, but I am informed by my associate on his photostatic copies, those entries have been made. So from now on, I am going to hand the witness a clean photostatic copy of each page.

The Witness: I believe that the entire page of August 9, 1927, that I have here is in my handwriting. The entries thereon were made on the date in the upper left-hand corner, August 9, 1927.

I have the record here of August 10, 1928, in my handwriting, with the exception of a witnessed signature, which I see on the bottom. I will read:

"Methods of using tilted wires in combination, in order to illustrate the principles involved, a 3 lambda."—

which indicates wave length—"tilted wire is used as an element."

So far as I can see, this is much the same as the previously [fol. 522] discussed conception. This appears to be in general appearance a reproduction of a previous conception.

On the lower part of the page, I see arrangements which differ from that on the upper part of the page, only in that the element was added in an upper direction—I shall refer to the copy for anyone who wishes to see what I mean by that.

It is just merely another means—a means that was conceived at this time for employing tilted wires as elements.

The original was witnessed on 8/10/28 by C. R. Englund; Mr. Englund is one of my associates in my company.

I think it is true that, with the exception of the statement that I have last read into the record, and Mr. Englund's signature, all of the entries on this page of August 10, 1928, are in my handwriting. The entries were made on the date indicated opposite my signature, which is near the lower right hand part of the paper. It says, "Signed, E. Bruce"—August 10, 1928.

My attention is called to the fact that that last page that I referred to, prior to the one of August 10, 1928, was August 9, 1927. As to what I did in connection with this subject matter during that period of one year: As these different items have been conceived, there has been a vast amount of work in checking both theoretically and by experiments, variations alteration to the experiment, such as varying the length of the wire. Calculations were being made and theoretical plots have been made, and experimental checks of the plots have been attempted, and there is a vast amount of work which I have in my note book here which was done in the intervening period.

[fol. 523] The Court: These curves that have been considered now, they represent your best results, do they?

The Witness: I think in general—these are the conception of the first experimental results, they are not the best result.

The curve of July 26, 1928, is entirely in my handwriting. It was made on July 26, 1928, by me.

I think this is a plot of data obtained in a test on what I have termed an inverted V antenna, each element being four wave lengths long. The coordinate of the plots, for the abscissa, reads: "V vertical in degrees," and the angles are indicated: the ordinate reads, again, "in T. U. over half wave vertical." What is implied there is that we compare the output of the receiver connected to an inverted V antenna as described to the output of the same receiver when it was connected to a half wave vertical antenna.

The difference between T. U. has been plotted as the ordinate. In the center of the paper is a dotted line which says theoretical optimum angle.

Again, I would like to mention that I mean by theoretical optimum angle, the angle given by the predominating principle that governs the layout of these antennas.

Of course, as I have said before, there are other small factors, which I prefer to call correction factors, which

slightly alter the result, but in spite of these small correction factors, we show here experimental evidence that the check is reasonably good with that of the theoretical optimum angle as indicated.

From August, 1927, to the 1st of August, 1928, I personally devoted time to that subject, research along that [fol. 524] line. I can certainly say that the majority of my time for my company was employed during that period, in scientific research of tilted wire antennae.

Mr. Darby: I will offer in evidence at this time, the photostatic copy of the chart referred to by the witness.

(Marked Defendant's Exhibit LL in evidence.)

The next record I have is March 5, 1930. Reading on the top, this sheet says: "continued", evidently from a preceding sheet, "antenna schemes for horizontally polarized wires." Seven different schemes have been set down on paper in order that they may be compared, and I think only the last one is of interest.

Incidentally, I do not believe this is the earliest construction date of this, if I may refer to my notebook, perhaps I can dig that up. This is a witnessed paper of the conception, rather than the individual antenna involved.

Confining myself to the last sketch on this paper indicated as No. 7, it says: "Horizontal double Vee." There is indicated a plan view of layout using four elements as has been taught by the principles which I have discussed. There are certain notations on here, certain wave directions assumed, I see, on the right. I see in the center, the general diamond formation, where it says, "L minus lambda over 2." That is intended to indicate that the projection of the wire on the wave direction is a half wave length less than the length of the wire. As this is a right triangle and two sides have been determined, the angle is correspondingly determined by anyone who wishes.

[fol. 525] The item is signed with my signature with the date of March 5, 1930, and is witnessed, I see the signature of H. T. Friis, March 5, 1930.

Q. 98. Now, I notice that there are nearly two years intervening between the date of the last entry that you have referred to and the record that you have last referred to. During that period, did you do any work in research along the line of these antennæ that you have testified about?

A. That is very true.

In research work of this nature it was hoped that we would not be so narrow as to confine our attentions to one particular type, excluding all other types, but to carry the development along of a number of types simultaneously in order, when they were finally developed, that we may compare those types and select.

During this interval of time there were quite a number of types of antennas which were conceived, calculated theoretically and experimented with, all of the progress going along as a unit, with the intention of comparing the types when completed. Of this work during those two years in research on antennas of this character, all has either been done by myself or under my direct supervision. As to what proportion of my time, during this two-year interval, was devoted to research on antennas: If I remember correctly, I was sent to England on other work for a period of time and other than that period, I can answer your question by saying the majority of my time was on this work. I am referring to a second trip to England—speaking from memory, I would say I was in England on this second trip approximately four months. To be absolutely certain of the year, I would have to look up that date. It may possibly be 1929, I am not sure.

[fol. 526] Q. 105. Now, referring momentarily to the curve which is in evidence as Defendant's Exhibit JJ, will you state what enables you to fix the time, as you have fixed it in answer to a previous question, or at least the range of time within which, to the best of your recollection, you discussed this with Mr. Couzens of the Patent Department of your company?

A. I disclosed the exhibit in question to Mr. Couzens on a visit that he made to Cliffwood, New Jersey, where I was working at that time.

At a later date, or first I should say it is my understanding, or I am fairly certain that I saw Mr. Couzens in his own handwriting, sketch a similar sketch to the one that we have discussed, and I signed the paper. He took that away with him.

After a period I realized the importance that that particular paper might be and I spoke to Mr. Friis about it. He was going to New York and I requested him to speak to Mr. Couzens about the whereabouts of this paper. As a result of that visit, I received a letter from Mr. Couzens which you

have just handed me. I recognize Mr. Couzens' handwriting. That is Mr. Couzens' handwriting because I have the original letter of which this is a photostat. This letter from Mr. Couzens was sent by mail and I received it.

Our company, to my knowledge, has erected commercial antennas embodying the results of my research work as I have outlined it. As to the stations: Rather than speaking from hearsay, I will only mention those that I have actually looked at myself. I have seen one such antenna which was erected at the ship to shore station of the American Tele- [fol. 527] phone & Telegraph Company at Forked River, New Jersey. I have seen that.

Another antenna of this general type (which I have seen) was erected at Netcong, New Jersey. I believe that antenna was intended for communication with Bermuda. At least I have a distinct recollection of those two stations. I understand that there are others.

You ask me what a rhombic antenna is: There has been evolution of names for this type of antenna. I first called that general form a double V, which admittedly is a crude term. I thought that the expression "diamond shape" was a little more descriptive in that it indicated that there was an opposite relation between the two V's. There again, it was a crude term.

Finally, looking up the technical term for that shape, a diamond shape, why, rhombic fitted the case, and from that time on this antenna has been known as a rhombic antenna.

The commercial stations that I referred to as having seen, or known of their existence of my own knowledge, these were all rhombic type.

I have received scientific honors for the work which I have done, especially citing my work on this antenna research. To be strictly accurate, I would like to see the citations in each case that accompanied such honors. I think they were a little broader than covering this subject. However, the subject was mentioned. As I recall, in 1932, the Institute of Radio Engineers awarded me the Liebman Memorial Prize, which I believe is given as their selection of the papers that have been presented to the Institute during the year.

[fol. 528] In 1935, I received the Wetherall Medal of the Franklin Institute, which again had a broad citation, but

in the citation was mentioned the work concerning rhombic antennas.

I referred to a paper in connection with the Liebman Memorial Prize of the I. R. E. I prepared a paper and submitted it to the Institute, and they suggested that it be given personally at their Sixth Annual Convention on July 6, 1931, at Chicago.

Circumstances prevented me from attending that meeting, but Mr. A. C. Beck, who has assisted me in a great deal of this work, gave the paper in my stead. The convention may have lasted for several days, but it was within the vicinity of that date. The paper was subsequently published in the Proceedings of the I. R. E. I have here the Proceedings of the I. R. E. of August, 1931, in which I see the paper in question.

I mentioned that Mr. A. C. Beck assisted me; Mr. L. R. Lowry similarly assisted me during that period in 1928 in my research work.

Mr. Darby: I offer in evidence as one exhibit the photostatic copies of the pages under dates of May 13, 1926, May 14, 1926, the second page of May 14, 1926, July 19 to 21, 1927, August 2, 1927, August 9, 1927, August 10, 1928, March 5, 1930, and the Bruce letter of July 25, 1927, that is, the Couzens letter to Bruce. If there is any question about this last proof, Mr. Couzens will be my next witness.

(Marked Defendant's Exhibit MM in evidence.)

[fol. 529] Cross-examination.

By Mr. Brown:

The Witness: I have been specializing as a research engineer for the American Telephone & Telegraph Company on short-wave radio communication since about 1924. Also I have had working with me and under my supervision a number of similarly trained radio engineers. Of course I know a lot more about this subject now than I did say in 1926, 1927 and 1928; there is no question about that.

X Q. 131. And I assume that in going over your notebook, and so forth, and telling us what they represent, that it is only fair to say that you are interpreting them in the light of what you now know, is that right?

A. I am not certain that that is right; I have tried to interpret them in the knowledge of the times.

X Q. 132. Well, of course, you recall and I recall that a number of times you stepped off the page of your notebook and told us a number of things outside of that, and I assume that you were telling us what you now know or think you know to be a fact.

The Court: Did you go outside of your notes at all, and if you did, then——

The Witness: He is referring to the particular diagrams, and in my attempt to interpret them in terms of my knowledge at the time they were made—I thing in a number of cases that if you had asked me to interpret those in terms of personal knowledge, I may add features—. I have attempted, to the best of my ability, to answer as of the date of my notes.

[fol. 530] I approached this study by examining the prior art, reading the prior art; one of the things in that that interested me was the so-called wave antenna. That the wave antenna is one that depends upon the tilt of the wave which you might say traverses the wire, is what was taught by the reading material that I had at hand.

In reading this material, the wave antenna, as I understood it, was extended substantially horizontal. There exists a wave tilt and you have to accept as a physical fact the angle between that epuiphase wave front in the wire in question, and in my first experiment, which I described to the best of my ability, I had precisely that feature in mind.

The first experiment that I described, as dated May 13, 1926, consisted of one wire substantially horizontal.

That wire was intended to work in the manner in which wave antennas worked, that is, it was approached by a wave with a tilt. The thing that I hoped to achieve by this test was so to arrange a second wire in relation to that first wire so that the useful component of the electric vector of that wave front would induce, in the second wire, a similar magnitude to that of the first wire, but so phased that the result would be cumulative at the receiver, and in my opinion that was achieved, to some extent, at any rate, by this initial experiment.

I did not know the wave tilt, therefore I have variables of the divergences of the wire involved here, always keep-

ing the horizontal wire fixed, as teachings of wave antenna practice had recommended, and adjusting the second wire in relation to the first so that the induced voltages cor- [fol. 531] respond with proper phase relations to be cumulative at the receiver. I was using a horizontal wire as the old wave antenna; I tried to explain that the wire was substantially horizontal, there existed the wave tilt from the surface wave which arrived at the distant oscillator. Incidentally, I have tested that; I know that there is a wave tilt there. I can prove it from experiments. In relation to the wire, I tried to put a second similar wire so the voltages appearing in the wire would correspond to the voltage in the first wire, but so connected in the receiver that the result is cumulative. Now what I am trying to say here is that I wanted these two wires to perform in the same manner. This was an experiment which led to the discovery that there was an angle between those wires which was beneficial. My first conception was based on just the attempt to get the same magnitude in the two wires. My later conception of how the thing worked, taught me that I was not performing it in the most desirable manner; I was performing it in a manner which was helpful, but there were other manners which were more so. And this first experiment does not involve necessarily the critical angles which are described on the exhibit of September 28, 1926.

I went on with further experiment to determine just what would be the optimum tilt of this wire which I was going to incline upward from the earth. What I arrived at as a general proposition was that the length of the wire which was inclined to the earth's surface should be a half wave length longer than its projection upon the earth's surface, in reference to the wave direction assumed. In other words, what I arrived at was, assuming six inches of [fol. 532] this rule to be a half wave length, that the proper rule for determining the angularity of my wire was that where the wire was three half wave lengths, that a vertical line dropped from its end would determine the length of the line, which was only two half wave lengths in the horizontal. I was assuming that the wave arrived in a horizontal direction; in this case, there isn't any difference, but I do not want any misunderstanding when we get to other cases.

X Q. 149. Well, as far as the notes you have produced are concerned, they have all assumed that the wave arrived in the horizontal direction, and therefore this line which determines the projection, that is the projection of the tilted wire, would be on the horizontal plane, wouldn't it?

A. In relation to this work, the construction was under an ideal basis——

X Q. 151. Isn't what I said right, about the notes you have produced, isn't that the way all of the notes you have produced read, and isn't that the figure you show in each case, that you assume that the wave is arriving in the true horizontal direction, and your wires are tilted up from that horizontal plane, and their length of angle is determined by the rule or law that the projection of that wire shown on the horizontal plane would be a half wave length less than the length of the wire itself?

A. Where the plane is sufficiently good to represent a mirror.

X Q. 152. I am talking about what your notes show, Mr. Bruce.

A. Yes, that is right, that the conception of September 1928 follows your description.

Everything I have produced is exactly that way, that law that I have stated, that the angle of my wire to the [fol. 533] direction of the arriving wave that I have assumed is determined in length by the rule that the length of my wire shall be a half wave length longer than the projection of that wire on the line of the signal received. I would like to point out in that connection, I have tried to say, that that was the dominating rule. Like all things in nature, there are slight things which detract from the dominating rule, and have slight variations, and I thoroughly appreciated that and I believe I can substantiate that claim.

It is correct that every antenna that is referred to in my notes up until some time in 1930, was either a single wire tilted up at an angle to the horizontal plane, or else a V arrangement in a vertical plane with the open end of the V down against the ground or towards the ground, and with the apex of the V at the top. In every case, each of these antennas was fed, in the case of a transmitting antenna, or the receiver was located, if it was a receiving antenna, at one corner or one end of the V.

X Q. 157. In no case, was the V divided at the apex and the two sides separately connected to the receiver or transmitter?

A. I wish you would qualify that last statement to include the first experiment which I performed. I am referring to having two elements at divergence with the apparatus connected in between, which is the first experiments performed.

X Q. 159. With the exception of your experiment of May 13th and 14th, what I have said is correct, I believe, isn't it?

A. Correct for the particular pages discussed.

At the bottom of that figure on my notebook page of August 10, 1928, I showed the V arranged differently from [fol. 534] the showing of any of my other notebook entries in that it was, you might say, turned on its side with one of the corners at the bottom, and with the apex pointing in horizontal direction. After this conception, I had Mr. Beck and Lowry test this particular arrangement. If my recollection is correct, for the length indicated on this figure of 3 wave lengths, it was not a very good antenna, but they found that there were other lengths in which the antenna was not at fault. I don't believe that the particular thing shown on my notebook page would give any worth while results as a receiving antenna.

May I say that in all the work—I don't know how this page was selected for evidence—but I have mistakes as well as useful things that occur. Even to a research engineer like myself, a good many things that I put down on paper may not work out when I put them to practical use.

I did some reading and study of the prior art, before I approached this subject. I was familiar with a certain article written by Levin and Young in which there are certain formulas quoted. I have never seen an article written by a man named Abraham directly. I had this Levin and Young article in mind in working out these antennas. It was published at a vital time in my work—I was very much impressed with its importance in connection with my work, and I have placed it in my daily notebook here for reference.

I made a note at that time, and yet, I went on with my research and experimentation in trying out these straight wire antennas for a number of years afterward, before I arrived at my rhombic antenna.

[fol. 535] I said that I knew of two rhombic antennas that had been erected by the American Telephone and Telegraph Company. I do not know when they were erected. I would have to refresh my memory, if I am to be held to a certain date as to when I saw them. They were erected pursuant to my research and development of the rhombic antenna.

I presume they certainly would have been after my sketch which was produced here as some time in 1930.

In my tests of May 13th and 14th, particularly that shown on my notebook of May 14th, where I said I made some directivity tests (1926). I had there an antenna comprising a horizontal wire, and a tilted wire running from the receiver. The transmitter was the element that was moved; I moved that around my antenna. It is substantially correct that all of my measurements for directivity were taken in the horizontal plane.

X Q. 184. And there is nothing on those two notebook pages of May 13th and 14th to indicate any determination of directivity in the plane of the two wires of the antenna, is there?

A. Merely that it is implied by the fact that——

X Q. 185. Will you answer my question first, and then you can say anything else you want?

A. I am not certain that that is true.

(The Reporter repeated the question.)

X Q. (Continuing.) I say, other than in the horizontal plane?

A. There is no direct tests other than the possibility—you may not be satisfied with that—the fact that the divergence of the wires was varied. But when you had read the early readings which I had, which indicate that gains are achieved [fol. 536] partially through increases in the directivity of the antenna, I felt that in the vertical plane, the same as I had been taught by wave antenna literature that I had read, that there is certainly a directivity expressed there, and I was familiar with that at the time. And I was attempting to correlate to elements here and got a very end result, and I am certain that I felt that there was something there, but I was unable to measure it on this particular date. I certainly did not put anything down on those notebook pages about it.

Then over on the notebook page of July 19, 1927, I was still experimenting with this single-tilted wire runni. up to the top of the pole. I was still experimenting there with the question of the best length of wire and the best angle, because every time I changed the length I changed the angle to the horizontal. I was striving to find the optimum for each length.

As to what I put down as being the thing I determined at that time as being important: I see by the column labeled T. U. that a greater output was achieved for the four wave length case, than any of the shorter lengths. I do not see that the angle at which that four wave lengths was used is written on this page. However, the angle is determined from the dimensions given or can be determined. I made a column for the angle, but did not fill it in; that phi up there in next to the last column is intended to indicate that angle. Phi has been a symbol for me in this work as the angle between the pole and the wire. It would not make any difference if I called that angle theta. [fol. 537] In the sketch in the middle of my notes of July 19, 1927, I have indicated there the distance D as being from the foot of the pole to the receiver. Then, at different times, I indicate wires of a number of different wave lengths. I think in that particular case, lengths were added to the existing wire, which is equivalent to a longer wire. It is not correct that each time my wire would extend up to the top of the pole. There was a fixed pulley at the top of the pole, and I tried to explain in the testimony that there was a rope that ran over that pulley, and as we varied the length of the wire and also the position of the receiver at the base of the pole, we always tightened up on that rope so that there was no slack. That, of course, for a long wire would take the receiver, if it is remote from the transmitter, I mean the remote side of the pole, that would mean the whole system is very slightly moved away from the transmitter. But since the transmitter is at a distance and that variation in distance is only small, why, it is not vital in my opinion in this experiment.

The distance D as shown on my sketch does not represent correctly the projection of the wire on the ground.

X Q. 202. And you mean D meant the projection and not the distance to the bottom of the pole, or did it mean the distance to the bottom of the pole?

A. I gather from the diagram here that the arrows point to the foot of the poles, so I am certain that that is the way it was measured for this experiment. The wire would not have made a projection equivalent to distance D in each case.

The note I made on that experiment simply was that the experiment showed that it was apparently important to [fol. 538] avoid sagging in the tilted wire. Just to help you, may I say, though, that that distance that you are interested in, can, I believe, be determined by such dimensions as are given here. Let me see: The height of the pole would have to be known, in order to do that. This happened to be a steel tower which is still in existence down at the location D on Vesey Street. That doesn't appear in my notebook, so we apparently couldn't do it without knowing the height of the tower.

In the beginning of m. testimony yesterday afternoon, I said that the cost of the antenna was one of the considerations.

I was working on these experiments from May of 1926 on up through 1930, on these various forms of straight wire antennas, and some time after that, the Telephone Company built two of my rhombic antennas. I don't know the comparative cost of my rhombic antennas and antennas that were being built by the Telephone Company between 1926 and up to the time that it built my rhombic antenna.

X Q. 212. Do you know whether there is a very great difference in the cost—if you don't know quantitatively, do you know in a way that you can give us a general comparison of cost of erecting one of your rhombic antennas as compared to antennas that were being erected by the Telephone Company during the period of 1926 to 1930?

A. The only knowledge that I have on the subjects of costs are these:

Much of my efforts, which has not been brought out in this evidence, is to have antenna that is not restricted to a single wave length, but can be used on a number of wave [fol. 539] lengths and that to me seemed to be considerable economy.

I have expressed such things in publications where at one time we were required to build a number of structures, and following my teachings, they only had to build one structure, and it is obvious, just comparing the amount

of material involved, that the rhombic antenna would be cheaper than a number of these other structures; I believe very much cheaper.

I came here voluntarily.

Mr. Brown: Mr. Darby, do you admit it to be a fact that Mr. Bruce has an application for a patent, into which his attorneys have copied claims out of one of the Lindenblad patents here in suit?

Mr. Darby: I admit that to be a fact, that there is an interference pending between an application of Mr. Bruce and the second Lindenblad patent. That is a fact, but I do not admit that it is relevant to this controversy.

Mr. Brown: And you admit also that none of the claims involved in suit here are involved in that interference?

Mr. Darby: If you state that as a fact, I will admit it, but I do not see that it is relevant in this matter.

The Witness: Referring to the antenna, which I called a rhombic antenna, that is shown on my notebook page of March 5, 1930, at the bottom of the page, as drawn, it is substantially unidirectional, because of the attempt of terminating the far end. As to how I make that antenna into a [fol. 540] unidirectional as distinguished from a bidirectional antenna, as shown on this sketch: There is indicated on the far end resistance which is labeled Z sub zero sine pi. Removing that resistance, it alters the impedance somewhat of the antenna and requires somewhat rematching of impedances at the opposite ends, that being assumed, I suppose. After rematching, in examining the front to back, or I should say tendency towards unidirectional characteristic, one would find that there was a tendency towards unidirectional characteristic due primarily to the attenuation along the wires involved, but on inserting this device at the end of the wire and properly adjusting the device, a very much better tendency towards unidirectional antenna can be achieved. It is substantially true that that adjusting device which I have there at the end of my antenna, which is toward the direction from which the waves come, absorbs the waves that would be set up on that antenna in one direction, so as to produce a traveling wave antenna in fact.

X Q. 225. I will ask him to just tell us what effect this resistance element that you have marked ZO, isn't it, in

your sketch of March 5, 1930, has in the matter of absorption of power that is received by that antenna?

A. I think this question has been answered in publications referred to to some extent, but I will elaborate on it. If the direction of waves is in the direction as indicated as we go along the wires, there is an accumulative effect which builds up in the receiver. Should that receiver be so matched into your system so that there is no reflection, nothing travels, naturally, to the far end via that reflection.

[fol. 541] Now, we can examine in the opposite direction. If one goes along the wire and finds out from this wave what voltage appears across that at the far end, they will find, even though that impedance is not there, that the voltage between those two points approaches zero for a case receiver.

As a further explanation of what I have said, suppose we put the wave direction on the opposite side towards the receiver. Let us assume that the receiver and this far end termination are substantially the same elements, which would be pretty close to the actual fact. I have explained when the wave comes from the right there is a voltage accumulation across the terminal points from the source of that wave, and that practically no voltage appears across the circuit element that is nearest to the direction of that wave.

Now, just interchanging the direction of the wave just merely reverses that behavior. What we formerly called the receiver that could accumulate effects now becomes the far end termination which we previously had said had no appreciable voltage. Therefore, the receiver has no appreciable voltage, and the energy which travels to the far end, which now acts like the receiver end previously, absorbs the energy from that direction.

X Q. 229. Isn't it a fact that at one end of this rhombic antenna you have a receiver, and at the other end you have an absorption resistance circuit, and that you get unidirectivity by letting the waves or energy, whatever you want to call them, from one direction go through to the receiver, and in the other direction let them be absorbed by this resistance element?

A. When the wave is in the improper direction, 180 de- [fol. 542] grees improper, why, the energy of the wave is absorbed at the far end termination.

I achieved unidirectivity with this rhombic antenna by absorbing the waves at one end in an element which does not use those waves in any way for producing signalling effects.

X Q. 232. Now, on the page dated March 5, 1930, at the top, you have still a different kind of antenna shown, haven't you?

A. I wish you would not discuss that. It does show that at that time I was working with something else besides this rhombic antenna.

This rhombic antenna that I have told you about is, in the embodiment under discussion, composed of four sides arranged substantially in a diamond shape in which I position my receiver or transmitter, as the case may be, in one corner, and then this absorbing resistance that I talked about at the other end, in case I want it to be unidirectional, and then the wires between are serially connected together, that is, one wire running around there. The V element that is used in my rhombic antenna is this wire which runs from one end to the other and with the two wires connected together at that apex; that is the V which I referred to when I called it an inverted V.

X Q. 238. When you speak of the V in your notes you are talking about this inverted V that is set up over the ground, is that right?

A. A V to me is a description of a structure—any structure that is a V.

X Q. 239. I am asking you what you talked about on your direct examination when you spoke of V's. Now, as I recall, the only V's that you talked about were where you put up two tilted wires in a vertical plane, a practical V turned upside down?

[fol. 543] A. With the exception of when you get into the rhombic discussion.

X Q. 240. Well, your rhombic antenna is made up of putting two of these V's you might say, point to point, isn't it?

A. I would say with the proper apparatus.

X Q. 24.. I mean as shown on your notebook page, that is true?

A. Point to point, or diamond formation, with the apparatus at the terminals.

As a matter of fact, these V's that I talked about, these inverted V's as shown in my notebooks before 1930, were erected in a vertical plane.

X Q. 243. What would be the direction of transmission or reception in so far as they had directivity, with respect, you might say, to the geometric shape of the V? Would it be along the bisector of the angle of the V or at right angles to the bisector of the angle of the V?

A. In order to accurately answer that question we have a distance which I wish you would name. For instance, the surface wave which I have mentioned frequently dies out at great distances and is inappreciable, and we have a space wave.

In every instance, my notebooks—where they have any indication of directivity—have an arrow pointing indicating a horizontal direction with respect to these vertical V's; the conditions are assumed in the ground, I mean perfect reflecting ground was implied there, to suit those conditions.

Under those conditions, the directivity of the V's that I showed in my notebook was at right angles to the bisector of the angle between the two wires that went to make up my inverted V.

I have spoken a number of times of perfect ground. Of course, you never have perfect ground in practical antenna work.

[fol. 544] Although you would not have the actual horizontal directivity of transmission or reception that is indicated on these notebook pages, you would have them very close to that in the case of vertically polarized waves.

X Q. 250. What horizontal polarized waves?

A. I don't believe any horizontal directivity has been given——

X Q. 251. If I understand rightly, these antennas you are talking about would not receive horizontally polarized waves, is that right?

A. In the latter part of the testimony horizontal antennas were discussed, if I remember rightly.

X Q. 252. That was the rhomboid antenna, and in the 1930 notes?

A. Yes.

X Q. 253. If I understand you correctly, then, everything that you show before that was limited in its ability to receive to vertically polarized waves?

A. As indicated on the sketches; however, I would like to say that any technician working on this subject has the job of lining up the plane of this arrangement with whatever the plane of the electric vector is. The assumption of perfect ground is a helpful means of allowing him to get his ideas. The elementary theory on such subjects usually takes one off in space and tells you to line up the component of the wire involved so that it is parallel to the electric vector.

X Q. 256. Isn't it a fact that the arrangements actually shown on your notebook pages, prior to 1930, were adapted only to receive vertically polarized waves?

A. Well, in the evidence before us, I believe that is all that was discussed, other than the rhombus antenna.

[fol. 545] I referred to receiving from the Franklin Institute the Wetherall Medal; as a matter of fact, it was the Longstreth Medal.

The unit that I used in my notes of August 9, 1927, where I refer to deflection as an indication of a true signal, to show the improved signal, that is not the same unit that I use, for example, in my notes of May 13, 1926. The units employed here are deflections in microamps, which are roughly proportional to the square of the input voltage.

Previously I discussed two other types of units, one was the ratio of voltage which was on the earlier testimony, and the later testimony was in T. U. units, which today we call D. B. I was not talking about the same measurements in those two.

I spoke about making a couple of trips to England; they were on business in connection with short wave antenna development.

X Q. 264. Now, will you refer, please, to your notebook page of March 5, 1930, and I note that that is marked, at the top apparently as page 2. I will ask you whether there is anything on page 1 referring to horizontal rhombic antennas?

A. No, there is nothing relating to horizontal rhombic antennas on page 1.

X Q. 266. Now, still referring to your page of March 5, 1930, and to the rhombic antenna which is shown at the bottom of that page, and recalling your testimony this morning to the effect that these antennas were equivalent whether used as receivers or transmitters, will you tell us whether

you know as a fact, if the receiver is replaced by a transmitter in that arrangement, what percentage of the total input power would be wasted in resistance C0 at the end of the antenna?

[fol. 546] A. I understand that the power that went into that resistance would be absorbed and not radiated, is that right?

A. For the wave in what I call the back direction.

X Q. 268. Then can you tell me approximately what percentage would be absorbed—power input?

A. Well, it would be a very large proportion. It would be 40 or 50 per cent or possibly more. As to the radiating efficiency of that particular antenna, when used as a transmitter: If we are willing to acknowledge that the removal of that resistance changes the impedance of the system, and we are permitted to rematch the apparatus, then the forms are nearly comparable, but in removing the resistance that sort of effect does take place, but provided we make such a readjustment—

X Q. 275. I am merely asking you about the antenna as it is, not as you might perhaps rearrange it. You said, this morning, something about a reciprocity rule that these antennas were the same whether used as a transmitter or receiver. I am asking you about a transmitter where it is changed to a receiver. Tell me what would be the radiating efficiency of that antenna, leaving it just as it is.

A. That is quite a different question from the previous one you asked. I will answer the first question first. The effect of the far end termination, substantially, if I may ignore any slight readjustments in the impedances of the terminals, is substantially this: that with the resistance there, we may get a certain field strength at a distant receiver. There is power absorbed in the resistance from the transmitter. Now, if we take that resistance out substantially, the field strength in the distant receiver, at the distant receiving [fol. 547] point is unchanged. However, the power which previously was absorbed is now sent out in both directions.

Will you repeat the other question?

(X Q. 275 repeated by the reporter.)

A. To give a definite answer to the effect, leaving the transmitter just as it is, gives you a complicated situation. There are not enough precise values given to give a precise answer. I am referring to the mode of impedance mis-

matching that is effected. I assume you meant changing this system, removing the resistance at the far end, what happens?

X Q. 279. You have answered that question. I thought you answered that by saying then you would get radiations in both directions?

A. Yes, but probably I am talking about a minor detail whereas you are after the major detail.

X Q. 280. Can you or can you not tell me what is the effect, for the purpose of sending useful signal, of simply substituting a transmitter for the receiver in the antenna shown at the bottom of your notes of March 30th?

A. I will include in that a distant cooperating station. According to the theorem of reciprocity at the receiving station, the output of the receiver will be the same regardless of an interchange, regardless of the character of antenna connection at the two terminals. My reason for stating such is I believe the reciprocity law is valid where the circuit elements are linear. I mean by "linear" that if you double the voltage in the system, the current doubles. That is the definition of a linear system. If that condition holds, and I have no reason to expect a departure from that, in fact, experi- [fol. 548] ments made and observations made very closely show that to be true; then I think there is little difference in exchanging a transmitter and receiver, providing the transmitter's power is unchanged.

X Q. 282. Let us leave out the other receiver at the other end, and let us talk about strength of signals transmitted to a certain point that is coming out of these antennae. Now, will you tell me what is the proportion of power you can get in radiation in the form of a useful signal from that antenna with the resistance and without the resistance, and having a transmitter in place of the receiver.

A. If the circuit element is a transmitter, the forward radiation will be unchanged substantially whether that circuit element is in there or out. The function of that circuit element is this: When in there it absorbs the power which normally would be radiated backward if it were not present.

X Q. 284. Did you answer—just answer yes or no—did you answer as to the radiating efficiency of that antenna with that resistance in? If you did, I won't ask you to repeat it.

A. You want a yes or no answer to that, do you?

X Q. 285. You don't know the answer to that?

A. No, I don't know the answer to that.

Referring to my notes of July 19th and 21st, 1927, the second column there, the last entry, I made an arithmetical mistake in recording that as 2.1; that should be 3.1; it was just simply an error.

Referring to my notes of May 14, 1926, at the bottom I have a heading, "Top view directional characteristics". I did not make the same tests using the comparison loop for the receiving antenna.

[fol. 549] Referring to my notes of September 28, 1926, August 2, 1927, and August 10, 1928, and March 5, 1930; those are all theoretical.

Referring to my curve of July 26th, Exhibit LL, the inverted V on which I made the experiments upon which this curve is based of the same form (but differing in dimensions) as that shown on the top of my notes of August 10, 1928.

Referring to my notebook page of July 19th and 21st of 1927, there is nothing stated in so many words on that page to indicate that the measurements recorded are select measurements representing the best tilts of the various wire lengths used; however, it is my belief that these are optimum divisions.

The article entitled "Receiving Antennas", published in the Short Wave Transatlantic Radio of the Bell Telephone Magazine, commencing at page 42 of a pamphlet which has been put in evidence here as Plaintiff's Exhibit 22, is one that was written and submitted to me for approval. The actual composition of the paragraphs is not mine. It is published under my name.

X Q. 302. And do you accept responsibility for it or not?

A. I would like to read it closely before answering the question.

That article was published and put out over my name, as purporting to be the author, and was published in the Bell Telephone Magazine in July, 1928.

I wrote the article that was published in the Proceedings of the Institute of Radio Engineers for August of 1931, entitled "Development in Short Wave Directive Antennas".

Mr. Darby: I offer the article just referred to by opposing counsel in evidence.

[fol. 550] (Marked Defendant's Exhibit NN in evidence.)

By Mr. Brown:

X Q. 306. Mr. Bruce, I hand you a copy of British patent No. 392,201, and I ask you if that is the patent taken out by you or on application by you on your rhombic antenna?

A. By reading the first paragraph of the patent, that refers to me. I have never seen this before, and I would have to read it to answer your question.

X Q. 308. Well, take a good look at it and give us the best answer you can. Don't you know as a matter of fact whether that is a patent that was taken out on your rhombic antenna?

A. By examining the figure it looks to be the case. I undoubtedly have approved the application for that patent.

Mr. Brown: I ask that that be marked for identification.

(Marked Plaintiff's Exhibit 41 for identification.)

The Witness: United States patent No. 1,899,410, issued upon an application filed by me describing certain of the developments that I have described in my testimony this morning, with the exception of Fig. 16, which was added by amendment some time in 1931, in December. So far as I know, that correctly describes the invention that is purported to be set forth in that patent.

Mr. Brown: Now Mr. Darby, will you require us to put in a certified copy of the file to show that Fig. 16 and the text [fol. 551] describing it, was added by amendment in December, 1931?

Mr. Darby: I am perfectly willing to accept your statement of fact as to that, subject to any correction that the facts may necessitate.

Mr. Brown: Under Mr. Darby's consent, I offer during his proof the British patent as Plaintiff's Exhibit 41, previously having been marked for identification.

Mr. Darby: I object to it because of its lack of relevancy.

The Court: I will take it, subject to the right to him to move to strike out when you file your briefs.

Mr. Darby: I note an exception to the Court's ruling.

(Plaintiff's Exhibit 41 marked in evidence.)

Mr. Brown: Then I offer as Plaintiff's Exhibit 42 United States Patent 1,899,410, that has been referred to by the witness.

handwriting. I am not certain about the numbers above that. Some of them may have been in my handwriting. Two of us did this together. The other man was Mr. Lowry.

We were at this time doing experiments under Mr. Bruce's direction on antennas of his design.

Irrespective of whether I made the notes, I recall what was done; I assisted in the test.

We put up a half wave vertical wire, according to these notes, and the coupling to the set was two and a half turns above ground on a six-turn coil. We then wrote down that the attenuator setting for 80 microamperes change was 23TU and that the attenuator setting recorded here for [fol. 560] 30-30 microamperes was 89TU. That is a measurement of the gain of the receiver when the input was 30 microamperes and the output 30 microamperes.

We then subtracted those two to determine the amount of gain that was necessary in this receiver with this particular antenna connected and with the oscillator that we had placed out to measure these antennas. Having made that record we put up a one wave length wire and tilted it toward the oscillator. The coupling changed to one and one-half turns above ground on a six-turn coil. And the attenuation of the receiver for an 80-microampere deflection was 26 and the second deflection, the set gain, was 89. The difference here was 63, minus 63.

We then changed this antenna to a two wave length wire which was folded in the middle. We added another section to the top of this first one, which was one wave length long, as indicated by the symbol similar to a V turned on its side, after two lambda. The apex of the V was pointed toward the oscillator. The coupling remained one and one-half turns above ground on a six-turn coil. We have here a notation that the first top of the antenna was at the top of the pole, as high as we could hoist it, and the attenuation for an 80 microamp deflection was 23½. The second attenuation for 30-30 microamp deflection was 88, and the difference indicated as 64½.

We then lowered this same wire down one meter from the top of the pole. The first attenuation for an 80 microamp change was 23¼, and the second attenuation for a 30.30 microamp deflection was 88, which gave us a difference of attenuation of 64¾.

[fol. 561] The next notation here is not very plain. I do not know what this "meters down" indicates from this photostat. I assume it is a two, but I don't know that for sure. For that test alpha one for 80 microamp deflection was 22 and alpha 2 for 30-30 microamp deflection was 88, and the difference in attenuation was 66.

We continued on page 2, for four meters down, and five meters down, and six meters down, in the same manner.

Q. 17. Will you go on to the next stage and point out in what respect these series of experiments differ from the preceding one?

A. Do you mean page 2, under date of 8/16/28?

Page 3 under date of 8/16/28 starts off, 4 lambda. At the top of the page, the date 8/16/28 is in my handwriting. This is apparently continued from some other test of that date from the notation at the top of the page, and it starts with 4 lambda and then there is an indication of a diamond-shaped antenna.

We went on from the test that I described before and completed the diamond-shaped antenna.

4 lambda means that each element of this diamond was one wave length long. The coupling of this antenna to the set is now one turn above the ground on a six-turn coil.

One button pressed reverse to the receiver. There were buttons on it to determine the gain that was used.

The first notation is, with this at the top of the pole, of an alpha one with 80 microamp change is 22¾. Alpha 2 for a 30-30 microamp deflection is 87.5, and the difference is 64¾.

We then lowered it one meter and it was one meter down from the top of the pole and the attenuation for 80 micro-[fol. 562] amp deflection was 21, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 66.5. We lowered it to 2 meters down and alpha 1 for 80 microamp deflection was 19.5 and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 68.0.

With this same antenna three meters down, alpha 1 for 80 microamp deflection was 18.0, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 69.5.

We then lowered it to 4 meters down, and alpha 1 for 80

microamp deflection was 16.5, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 71.0.

Then at 5 meters down, alpha 1 for 80 microamp deflection was 13.5, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 74.0.

On page 4, under date of 8/16/28, we seem to have gone with the same antenna, from the heading, four wave length —an antenna with a diamond figuration sketched here, to eight meters down and alpha 1 for 80 microamp deflection is 17.0, and alpha 2 for 30-30 microamp deflection is 87.5, and the difference is 70.5.

These records were made under the date at the top of this page, 8/16/28.

Turning to the next page that is undated, but headed "Set No. 7", I believe the first of this is in my handwriting, lambda over 2, case 1, vertical filter switch closed, one button pressed, and the coupling was two and a half turns above ground on a six-turn coil, and for an 80 microampere deflection, alpha 1 was 22, and alpha 2 for a 29-29 microampere deflection was 87.5, and the difference was 65.5TU. I am not sure that that 65.5 is my handwriting now.

[fol. 563] I don't believe I worked with anyone else except Mr. Lowry and Mr. Bruce at this period.

Referring to the notes on this last page: The first thing we had was a wire one wave length long and we tilted it towards the oscillator and coupled it into matched impedances again and measured the output from that wire. We then took the same antenna and tilted it away from the oscillator and measured its response. We then built a two-section antenna, two wave lengths long, each wire one wave length long, similar to the preceding case, except that the apex of the V is now pointed away from the oscillator. This would indicate that we started to test this in the same manner because we have a column height from the top of the pole in meters, but there is an entry here only for zero.

I believe these photostats of pages numbered 24 to 33 inclusive are photostats of records kept by me during the period concerning which I have testified.

I continued experiments with various forms of tilted wire antennas under Mr. Bruce's direction during that period, and it was some time later that we moved the laboratory from Cliffwood to Homedale. When we moved and set up new structures, Mr. Bruce assigned me the job of build-

ing certain antenna structures on the new location, and this sheet, No. 25, which starts "Two lambda at 32.2", appears to be in Bruce's handwriting. It was a slip which he gave to me to locate the poles that we were to have set on this new location.

It is labeled "Long Farm", and at the top, upside down, it is labeled, "The edge of the wood", and a pointer 200 or [fol. 564] more, I presume, is feet, and these four poles that are marked 260 feet apart in one dimension, and 380 feet apart in the other dimension, seventy foot poles, were to be erected as soon as possible to build a horizontal rhombic antenna. It was not known by that name then. It is a horizontal V antenna, which was a continuation of these experiments.

There were some other hundred foot poles located a little farther on that were used for building other combinations of tilted wires to compare with this antenna, and from this sheet those poles were set——

The arrow "England" on the right hand side of the page meant that in surveying the location for those poles we were to take that as the great circle path from our station to Rugby, England, which was the transmitting station of the British Post Office that we used for testing these antennas. I don't remember when it was that Mr. Bruce gave me this sheet with these instructions. These poles, I believe, were set about the first of April, 1930. Mr. Bruce gave me this sheet with these instructions some time before, perhaps a month or two, I don't know; I don't remember when. I have no record of that date. It was before the first of April, 1930. But I don't know the exact date.

This sheet 24 which has a sketch of a horizontal double V antenna is in my handwriting, and it was evidently rather a piece of scratch paper on which I calculated the length of wire to use to build this antenna. Between the four poles that the other sketch located, it was to have four elements as shown here, each one four wave lengths long at 16.11 meters, so that the wire length was 64.44 meters, and the [fol. 565] dimensions are shown on this sketch with the angles between the wires.

In this group of sketches here, page 26, was a sketch that I made to indicate to our shop force the details of erecting this antenna. At the end it shows the transmission line that went from the end of the antenna down the pole to the small building that housed the equipment to be connected to

Mr. Darby: And I assume, Mr. Brown, that you have no objection to having a statement appear on the record at this time, which I likewise understand is the fact: Reference heretofore has been made to the fact that an application of Mr. Bruce's is involved in interference with one of the patents in suit, and I think it is the second Lindenblad patent. Now, I would like to complete that statement with this fact, which namely is, that a reissue application of this patent that has been offered in evidence as Plaintiff's Exhibit 42 is involved in interference.

[fol. 552] Mr. Tunick: The reissue application of this particular patent, as far as we know, is involved in interference, but not on any claims in suit.

By Mr. Brown:

X Q. 312. Is it or is it not a fact that this rhombic antenna developed by you has revolutionized the construction of short wave sending and receiving antennas as built and used by the American Telephone & Telegraph Company since 1931?

A. It is my understanding that that type of antenna is replacing previous types.

Redirect examination.

By Mr. Darby:

The article which you hand me appears to be the same Levin and Young article of 1926 proceedings of the IRE volume 14, pages 675-688, to which I referred.

Mr. Darby: I offer the photostatic copy in evidence.

(Marked Defendant's Exhibit OO in evidence.)

John H. Couzens, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination:

By Mr. Darby:

The Witness: I reside in Scarsdale, at the present time. I am associated with Bell Telephone Laboratories as patent

[fol. 553] solicitor and attorney. In 1926, my work as patent solicitor and attorney for the telephone company included antennas.

I wrote the letter dated 7/25/27 to Mr. Bruce, which is part of Defendant's Exhibit MM. I sent it to Mr. Bruce through the company mail.

I have seen a copy of the drawing Defendant's Exhibit JJ; to be exact, I saw it on Saturday, October 9, 1926. I witnessed a copy of that drawing. That is not my signature on that exhibit. I don't know what happened to the original copy that I witnessed, other than it is lost. I have endeavored to find it.

The facts set forth in this letter that I wrote July 25, 1927, are true.

Cross-examination.

By Mr. Brown:

The Witness: What I mean is that when I read the letter now, I think at the time I wrote it, I knew the facts as there shown. I would not say now that I remember all the facts without the letter; but I do recall the particular incident of writing the letter and also talking to Bruce about the tilted antenna.

CARL ROBERT ENGLUND, called as a witness in behalf of the defendant, having been duly sworn, was examined and testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Red Bank, New Jersey. I am associated with the Bell Telephone Laboratories. I am a member of the technical staff in charge of ultra-short wave [fol. 554] receiving work now. I have been employed by the Telephone Company in that capacity since 1914.

The nature of my work in 1926 to 1928 was entirely radio. I had something to do with antennae at that time.

I know Mr. Bruce. In 1926, Mr. Friis and I were supervisors in charge of the plant laboratory at Cliffwood, where Mr. Bruce worked. Technically, we were his immediate superiors.

The photostat of writing dated Friday, May 14, 1926, which you hand me is in my handwriting. I wrote it on May 14, 1926.

Mr. Bruce came in to see me in my office and discussed the work that he was doing at the time, and interested me in what seemed to me to be the multiple resonance effect that he was getting, so I asked him for details and he gave me the dimensions as noted down here on this paper—of his antenna. I later on made some calculations which complete the page.

In my capacity of supervisor or immediate superior to Mr. Bruce, I did not keep track of the work that Mr. Bruce was doing; Mr. Bruce was working more directly for Mr. Friis. He came in to consult with me on this particular occasion.

Mr. Darby: I offer in evidence the photostat of the record noted by the witness.

(Received and marked Defendant's Exhibit PP.)

The Court: When did you make these entries?

The Witness: I made these entries on the date written, May 14, 1926.

[fol. 555] Referring to a photostatic copy of a record dated August 10, 1928, in evidence in this case, as part of Defendant's Exhibit MM: the signature at the bottom of the page is my signature. As is customary in matters of this sort, Mr. Bruce came to me with this page and asked me to witness it and I signed it after reading it, as we usually do to make sure that I understood what it was about.

That is a technical matter for validating it.

Cross-examination.

By Mr. Brown:

The Witness: When Mr. Bruce told me about it, he did not tell me how these antennas worked. As I recall, he was a bit puzzled about what appeared to be some multiple resonance, and that is why I asked him for the details. Then he made some calculations, and then I think the matter lapsed. That was the point that seemed to be in his mind when he was showing this to me.

X Q. 20. When you say you understood the disclosure on these pages, that is what you understood?

A. The disclosure on that page is for two wires at an angle, with dimensions as given there.

When I said Mr. Bruce showed me the August 10, 1928, page, and that I read it over, and witnessed it, I meant by "witnessed it", I understood what Mr. Bruce had done, what was referred to by Mr. Bruce on that page. I do not know anything about the success of the antenna shown at the bottom of that page of August 10, 1928.

X Q. 23. Then your witnessing was, you simply read it over and signed the page?

[fol. 556] A. Mr. Bruce has here a diagram showing two legs of an antenna. In the center of each of those legs, an electromotive force is put. That is what I understood, the theory which——

X Q. 26. You looked simply at the page and understood that Mr. Bruce was telling you he had done something of that kind, but you do not mean to say you understood particularly how the thing worked, looking at that, do you?

A. That is what I say I understood, I understood how it was supposed to work, how it worked.

X Q. 27. Tell us how the diagram at the bottom of that page was supposed to work.

A. The wave impinging on the thing induces an emf in each of the legs and they are—the wire distance is a wave length longer than—let us see—3 lambda——

The principle involved, which is the thing that I understood at the time, is that of inducing emf's in conductors in such a manner that there would be a difference in the wire length to make up for them, to give the time lag so they would add up in series, the results would add up.

X Q. 28: You do not mean that, really, Mr. Englund, do you, because the very sketch you are looking at, shows the wires of equal length, doesn't it? Take another look at it.

A. No, but you see at the bottom of the page, the induced emf is directed to the right, in the center of the bottom leg, for example, there will be an electromotive force induced upwards. In the center of the top leg, there will be one induced downward, but the resulting current at the receiving point, since there is a difference in the wire length between them, will add up for the electromotive force.

[fol. 557] The explanation I gave you now, is how I understood from Mr. Bruce that that antenna works.

I do not believe directivity was mentioned.

Redirect examination.

By Mr. Darby:

The Witness: I went to see one of Mr. Bruce's antennas. That was the first exhibit, the original antenna on May 14, 1926. I went up to see the antenna a few days after that. I believe I did not see it in operation; it was just there.

HAROLD TRAPP FRIIS, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Rumson, New Jersey. I am associated with Bell Telephone Laboratories as research engineer. I have been so employed since 1919. From 1927 to 1930 the nature of my work was radio receiving work. That included specifically the subject of antennas.

I know Mr. Bruce. He worked for me in the company, associated in the work there.

Technically speaking, my rank relative to him, was nearest above him. I was the one to whom he immediately reported. I did not hold a sole position in that respect; Mr. Englund took part in that too. In general, I directed the work that was done by Mr. Bruce in antenna research. As far as possible, I kept myself familiar with the work that he was doing. In an organization of that type, where you [fol. 558] have a dozen engineers all doing research work in all kinds of lines, receiving sets, antennas, static measurements, measurement sets, attenuators, and so on, you cannot follow everything.

Referring to a written record of August 2, 1927, I recognize my signature on it. I recognize Mr. Bruce's handwriting. Bruce brought this record to me, or this page to me, and he asked me to witness it, as we used to do, and I read it through, understood it and signed it.

I also recognize the record of March of 1930. My signature is on that record as well. The circumstances of my signing that paper were similar to the circumstances in the other record. Mr. Bruce came in to me, or maybe I dropped

into his office, and he asked me to witness his suggestions here, this page. I read it through and understood it and witnessed it.

I did not keep familiar with the progress that Mr. Bruce was making, that is, the particular research work; I knew his work in general. I followed his work in general.

I knew what Mr. Bruce was doing in general throughout that entire period.

Cross-examination.

By Mr. Brown:

The Witness: I knew that the Bell Laboratories had been working on this problem of short wave transmission for a great many years. I knew too that they had been working on the problem of directive antenna for short waves for a great many years and that they had a number of skilled engineers during a number of years working on this problem, and leading up to the rhombic antenna of Bruce's.

[fol. 559] Alfred Charles Beck, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Red Bank, New Jersey. I am associated with Bell Telephone Laboratories, Inc. I am a member of the Technical Staff. I have been so employed by the Telephone Company since early in July, 1928, I believe it is. The nature of the work that I was engaged upon when I entered its employ was mainly short wave antenna development. My immediate superior under whom I worked was Bruce.

You hand me a set of photostats. This record is dated 8/16/28. Some of this is in my handwriting and some is not. This page starts in and the date on the top part, the printing, is not in my handwriting, but as we come down I cannot say—I know that where it starts with the second group, one lambda tilt towards the oscillator, that is my

the antenna. It shows that three insulators were used there to space the wires, and that each wire of the antenna was connected to a transmission line.

During the month of April that antenna was located from those sketches, and sheet 26, dated April 24, 1930, is a description of some tests made on this antenna after the construction was completed.

This is a horizontal antenna, horizontal V, as indicated by the heading of this sheet, and the front end, which here means the end towards England, away from the equipment, was left open and the local oscillator tuned to 16.11 meters was located approximately 825 feet away, both in front and in back of this antenna, and in front the receiving set attenuator read 19.0, and in back it read 11.8, giving a ratio of 7.2, the difference in those two readings for that connection.

"The front end open" meant that the horizontal V, as tested then, simply the two wires ended at the end toward England, there was no connection to any other apparatus at all at that front end.

Then this sheet continues as a record of a test of April 29, 1930. The ratio of horizontal to vertical pick-up, front [fol. 566] end open, oscillator approximately 820 feet in front at 16.1 meters, and with the impedance, this says maximum coupling, etc., which indicates that the impedance between the antenna transmission line and the receiver was carefully matched; and the reading was 30DB, that is the ratio of horizontal to vertical pick-up, which means that the oscillator having short rods was used with those rods turned horizontally and vertically, and the impedances in the set were rematched at each time, and this reading shows 30DB.

We then took a frequency run on that antenna, and the first two columns give the beating oscillator setting of the receiving set. They merely indicate the tuning of the set, so that any of those could be duplicated if we wished.

The next column is headed "Oscillator Setting", and refers to the numbers on the dial of the oscillator.

The next column is "Wave Length", and the next "Megacycles", in which there are only two readings shown here.

Then comes the DB column, also the receiving set response to this particular setting of the oscillator.

Then on the same page, further to the right, are remarks about the operation of the equipment at that time and the

effects observed; that is where it starts "Where the oscillator setting is 10", and so forth.

This is in my handwriting. I had assistance from some of the other people in taking them, but I was conducting them; they were working under my direction for this particular test, and I took the notes. Everything on this page is in my handwriting, except the notation written at right [fol. 567] angles, which is in, I presume, Mr. Bruce's handwriting, because it is signed with his initials. I recognize his handwriting. I don't know whether Mr. Bruce signed this in my presence.

These tests on this antenna continued, and the next sheet here indicates the data taken, it is dated 5/1/30. It is page No. 33, and it is headed "Comparative measurements on G. B. U., set No. 14, two buttons pressed." "G. B. U." is the call sign designation of the British Post Office transmitter in, I believe, Rugby, England. I likewise conducted this test, and received messages from G. B. U. in England, 5/1/30. This record was made on that date.

The record has on the right-hand column the time, P. M., daylight saving time. It starts at 2:45, 2.46 and entries are there indicating for each minute down that column.

The second column says that with one volt in the set gain for 100 out—that is, the deflection—on the V—which indicates that this antenna was 79.0; at the bottom of that column it is entered again 79.0 showing that the gain of the receiver remained constant.

The next column is headed "Lambda over 2 82.5." That indicates the set gain of the other receiver used with the half wave vertical comparison antenna remaining the same.

The next column is the attenuation for 100 microamps output on the V, and that was read from the set each minute opposite these times.

The next column is labeled "Vertical lambda over 2", and the attenuations were read.

The next column is labeled "Required gain." That column is the difference between the set gain of the receiver [fol. 568] 79.0, and the attenuation read is for 100 out. Each attenuation was subtracted from 79.

The next column is the half wave required again and that was obtained in the same manner by subtracting the readings on the half wave from the set gain of the half wave.

The last column is headed "V over lambda over 2." There is a difference between the two preceding columns

It shows the gain in decibels when receiving this transmitter of this antenna over the half wave vertical.

This indicates that we were using two antennas, the horizontal V that I have just described, and the half wave vertical antenna. "E button pressed" means "two buttons pressed." These receivers are double detection receivers which have shunts in the intermediate frequency amplifier that can be connected across the circuit or disconnected by the use of push buttons on the front of the set and that notation was there to show that two of those buttons were pressed in at the time these measurements were made.

There were several people assisting at this time in this work. I made the measurements on the V, as I remember it. The measurements on the half wave vertical were, I think, taken with an automatic recorder at that time, and that was operated by one of our technical assistants, either Mr. Desmond or Mr. Chapman, I am not sure which. I don't remember that Mr. Lowry assisted in this work.

At this time we were evidently making monthly work reports. The work reports for April and May of 1930 appear to be these photostatic sheets, that is, sheets Nos. 27, 28 and 29, April, and sheets 30, 31, for May.

[fol. 569] Mr. Darby: I offer in evidence the pages referred to by this witness, pages 1, 2, 3 and 4, of August 16, 1928; the next page undated; the next page showing the pole layout, undated; the next page showing the rhombic antenna layout, undated; the next page showing the detail of transmission line connection to the antenna; next page, dated April 24th and 29th, respectively; next one dated May 1, 1930; the three pages of April's work report, and two pages of May's work report.

(Marked Defendant's Exhibit QQ in evidence.)

The Witness: Those two work reports are in my handwriting. I cannot definitely recall when I made them, when I wrote them out. It was our custom to make these during the first week of the next month, normally. They were certainly made in 1930.

Cross-examination.

By Mr. Brown:

The Witness: I began work with the Laboratories early in July, 1928, and after a short period of introductory survey, of course, I went immediately to work under Mr.

Bruce's direction, probably before the 1st of August that year. I am not certain of the exact date. I still am an assistant to Mr. Bruce. During that period of 1928, or on up to 1930, the short-wave antennas that I erected and tested for Mr. Bruce were mostly of the long-wire type. I did not work with any other type at that time. I believe I could say that I worked with a variety of arrangements of long wires to make up antennas for short-wave work.

[fol. 570] X Q. 64. Now, aside from your notes, do you feel you could describe all of those antennas now, and tell us what they were and what results you got with them?

A. That is a hard question. Those which had particularly interesting results, in general, I remember quite definitely, but I don't know, to tell you the truth, just what I am relying on for my testimony. I would not be positive in saying that I could remember all of them without referring to these notes. I would hate to remember this one without exact details. In general I know the performance of the different combinations. And Friday, when I testified about the notes of 8/16/28, that is, the series of antennas that were tested by me and Mr. Lowry, I believe I practically read everything from those notes in giving my testimony.

As I go through those various arrangements there that are referred to, the final figure or number seems to be expressed in minus units; for example, referring to the first one on the first page, it is minus 66 T. U. All of the measurements on these pages are measured in that same unit, and the best signals, or best results are those in which the minus number is smallest. Looking at the first two, minus 66 is not, I believe, as good a result as the second which is minus 63 and so on. On that basis, I believe, the best results that were obtained in that series of tests was of the one wave length single wire tilted towards the oscillator as shown on the first page and the last page, in each of which we get minus 63 T. U. And referring back to the first page, my third group of notes refers to a two wave length antenna of the V form in which the apex of the V is pointed forward [fol. 571] toward the oscillator and the open ends in the other direction, and the V in a vertical plane; that arrangement, I believe, is the second best of the results obtained in our experiments of August 16, 1928.

X Q. 75. I have examined these notes rather carefully and don't find in them anything that shows how your antenna

was actually supported. Is there anything to show that, I mean in the notes themselves?

A. The notation is written here, starting in the middle of that first sheet, "Top of pole," and then, "One meter from top of pole," which would indicate that it was supported on a pole. That is all it shows about it. I believe there is nothing to indicate where the receiver was connected to the several antennas.

Our last experiment in these notes was one in which the V was turned with the open end towards the transmitter, the V being arranged in a vertical plane.

X Q. 79. But as to that experiment you did not record any results, did you?

A. This is not in my handwriting, but I would interpret that the first reading indicated a result which was not completed on these notes. The notes do not show a completion; they show it was started and a reading was taken.

These notes of August 16, 1928, show, on that same sheet, the response in the case of a wave length wire tilting away from the oscillator. I do not know the number on that sheet; it is headed "Set No. 7." The first entry is the half wave lambda over 2 case 1 vertical. That notation shows that we put up an antenna composed of a wire of one wave length tilted away from the oscillator; that alpha 1, 22.7TU is the result. It would be assumed that this alpha 2 in case [fol. 572] of subsequent tests like that, the gain of the receiver would remain constant. That notice immediately above, in the notes, holds for that test. The two could be combined and give the results of tilting away.

There are several pages here which refer to a diamond-shaped wire, and some of them indicate one meter down, two meters down, and so forth. As to what I mean by this "one meter down" with reference to that antenna: this antenna was supported by a single pole through the center of this diamond-shaped antenna. The supports to the corners, front and rear corners, were held from the ground out a little distance by ropes attached to stakes, and the center was held by a rope which went through a pulley on the top of the pole. In this first test where it says "Top of pole" the rope that went up to the pulley on the top of the pole was pulled up so that the top insulator went as high as we could get it, and the sides were pulled out tight by means of guy ropes, out to stakes.

In the next one, "one meter down", that antenna insulator was lowered so that it came down one meter from the top of this pole, and then the guides to the side corners were tightened again so that a change in the interior angles of the diamond was obtained. Our receiver was on the ground or near the ground, and we lowered the top of our antenna from the top of the pole. The receiver was inside a small building. The ends of the antenna went through the wall of the building to the set, and we made tests at that time in several ways, several different ways of connecting those wires. These wires came from the lower apex or corner of the diamond to the receiver, in each case.

[fol. 573] I am certain that Mr. Bruce must have been familiar with this experimental work that we did in August of 1928, as shown on these notes.

Referring back to the receiver that was used with this diamond-shaped antenna, the receiver was not connected to ground. During some of the tests, I believe that the antenna was connected to ground.

As to whether or not the notes show that the loudest signals were had in each particular case when that particular antenna under test was highest on the pole: That is true for the V pointed towards the oscillator on the first page, and for the diamond-shaped antenna. I cannot say whether it is true or not for the one tilted away from the oscillator because the data is not complete to indicate that.

X Q. 96. Please refer again to your notes of August 16, 1928, and tell us, for example, the third group there is marked 2 lambda, and then there is the V on its corner. Does that mean that each leg of the V was one wave length, or does it mean that each leg was two wave lengths?

A. I believe it means each leg was one wave length, the total length was two wave lengths.

X Q. 97. As far as your notes are concerned, they are not definite on that, are they?

A. I would take it that that meant that from these notes. I would say the same thing about the diamond on page 3 of my notes. That is what I now interpret the notes to mean. I remember quite well, because the pole height was such that that length must have been used.

Referring to page 24 of my notes, which shows the layout of the posts or diagram from which I calculated the wires to [fol. 574] be used in the antenna: that figure shows a general

geometric arrangement of the antenna that is referred to in these notes that I have produced today.

Referring to my page 26, which speaks of a "horizontal Vee". Referring back to my notebook, page 24, "Vee" was a name that we used at that time for the entire antenna structure, although it was rhomboid or four-sided in effect.

When I speak, on my page 32, of the "horizontal Vee, front end open", I meant that the antenna was mounted on top of 70-foot poles, and the transmission line ran from the rear end of the antenna down the pole and into a building to be connected either to an oscillator or a receiver, according to the tests that we were making. Here it was usually the receiver. The other end was open. This transmission line was connected to one corner of this rhomboid figure at one of the acute angles. As to what I meant when I said that the other end was open, the sketch on page 32 shows the way the ends were constructed in this particular system. That is a top view shown here, and the little sketch to the right shows how the transmission line, which being broadside—a single wire and the circles would indicate that it was a two-wire open line. The circles are spacer insulators. At the front end there was no connection to those wires, they ended at that. The insulation arrangement was similar to that shown on this page.

X Q. 109. Now, referring to the middle figure, which contains the transmission line legend, that only indicates one line connected to one wire of the antenna, is that right, so far as the sketch itself goes?

A. No, in a drawing in that plane there are two indicated, [fol. 575] where it says "Antenna", the single line refers to two, as shown in the other. That is a view at right angles or a side view, whereas the other is a top view. This is a working sketch rather than a perspective drawing.

X Q. 110. But as a matter of fact, or as a perspective view, you will admit that that is equally consistent with there being only one transmission line and one antenna wire—I mean connected to one antenna wire?

A. Not when I see these two together.

The transmission line would not be visible in the lower sketch, coming directly under the crosswise insulator, more insulators of the same type, spaced it as it went down, as indicated by the circles on the other drawing.

I have described the connections at the acute angles of this rhomboid; at the obtuse angles, that is, the intermediate angles of the diamond, the two wires at those two angles were serially connected; in effect, just one wire bent around that corner.

On page 26, the middle of the page, under date of April 29, 1930, I say, "the ratio of horizontal to vertical pick-up, front end open"; by "ratio of horizontal to vertical pick-up" I meant that in that test an oscillator was placed approximately 825 feet in front of the antenna and tuned to 16.1 meters; a reading was taken first on the receiving set when the short rods which radiated the field generated by the oscillator were in a horizontal position. Then the oscillator was turned so that its rods were vertical and in effect a substantially vertically polarized wave was received by the antenna, and that was found after recoupling the receiver to the antenna and retuning to extract the [fol. 576] maximum energy in each case, to give 30 decibels less antenna output.

The first test of this antenna for receiving actual signals from a distant station, that is recorded here, was on May 1, 1930. I believe I testified that this notation on the side of the page of April 24, 1930, my mark 26, which reads, "This page important to Patent Department. First tests on horizontal rhombic antenna. E. B." is in Mr. Bruce's handwriting. It appears to be.

Those signals that we received from G. B. U. were received to test the performance of the antenna in commercial service. These signals were sent as part of the commercial transatlantic circuit of the Bell System. Therefore we felt that these tests would indicate the performance of the antenna in commercial use. That is, we were using commercially sent signals to test this particular antenna.

X Q. 122. And referring to your page 26 again, the lower part of which has a number of tabulated readings, as I understand it, the tests there recorded are a comparison of the effects of vertical as against horizontal polarization and not tests of directivity, is that right?

A. There are three tests indicated on that page. The first one at the top is a test of directivity; the second is a test of the ratio of horizontal to vertical pick-up, and the third is a frequency run. The second and third have nothing to do with directivity. When I say that the top of that page

indicates directivity, I mean that it shows ratio of front and back reception of a distant oscillator when the front end was open.

[fol. 577] Lewis Reeder Lowery, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I am now employed by the Bell Telephone Laboratories. I reside at Red Bank, New Jersey. I am employed by the Bell Telephone Laboratories as a member of the technical staff. I have been so employed with the Bell Laboratories since June of 1927. The nature of my work, when I first entered their employ, was the investigation of various types of tilted wires under the direct supervision of Mr. Bruce. I was associated with Mr. Bruce in the work, and not with anyone else.

The nature of the work itself would be a comparison of the output of various elemental, simple forms of the V wire tilted in various manners, and endeavoring to find the maximum output in each case. The wires were used for a particular purpose in each case. The purpose of the wire was to, as I say, extract the maximum output of power or voltage in each case that we worked or attempted to investigate. I personally carried on that work under Mr. Bruce's supervision in 1927 and a portion of 1928.

I have a Bachelor of Science degree in electrical engineering from the University of Washington in Seattle.

After Mr. Beck had joined the company in 1928, I cooperated in some of the tests with Mr. Beck. These tests were very similar to the tests I had done in 1927, a continuation of the same type of research work. As to the [fol. 578] objective in making these various tests, it was the same general idea in each case; it was to conduct our elemental research on very simple forms of tilted wires to maximize the output in each case. There would be variations in lengths and various tilts of the simple forms, in each case attempting to find the maximum.

Referring to Defendant's Exhibit QQ, the top four pages of which bear the date August 16, 1928: part of the entries

on this page are in my handwriting; the other entries are in Mr. Beck's handwriting.

The work covered by this record is merely a continuation of the same work which I had been carrying on previous to the time Mr. Beck joined the organization. That record was made, according to the date shown in the upper right hand corner, 8/16/28. Apparently I co-operated with Mr. Beck on this test of 8/16/28; I believe all of the sheets herein refer to that date. After that time, I was engaged in testing other types of antenna, possibly not in co-operation with Mr. Beck. I am familiar with the work Mr. Beck was doing.

Q. 24. How was it possible for you to be familiar with the work that Mr. Beck was doing after your particular assignment to work with him had terminated?

A. Inasmuch as we were working under Mr. Bruce's supervision and along allied types of work, I would always have a general knowledge of the type of work which Mr. Beck was carrying on, although I may not have been engaged in it with him.

I was shifted to Homedale when the research work was shifted to that locality.

As to the fifth sheet in Defendant's Exhibit QQ that has a heading "Set No. 7," undated; not all of the entries [fol. 579] on the page are in my handwriting. The printing which starts lambda tilt toward oscillator—and I believe from there continuing on the rest of the page is in my handwriting. What is above that is in Mr. Beck's handwriting, I believe.

I was familiar with the erection of the rhombic type antenna at Homedale only in the connection that I was carrying on work on other types of antenna on a portion of the property immediately adjacent to the property where the rhombic antenna was erected. I was aware that the rhombic antenna was being erected. To the best of my knowledge, it was being erected in the year of 1930. I cannot give any closer approximation than that without recourse to such notes as I might have.

Cross-examination.

By Mr. Brown:

The Witness: Referring to the notes of 8/16/28, to the third page, where, at the top is shown a diamond-shaped

symbol, following the 4 lambda designation: in the test referred to on that page, the receiver was located in a small building immediately adjacent to the antenna. In back of this building, there was a pole which supported the antenna, at the top, by a rope running over a pulley, being connected to the antenna at the upper apex. The antenna was connected to the receiver in the building through the walls of the building. That was done by two short sections of wire. The receiver was not connected to the ground. According to the notes shown here, there is no designation showing other than that the antenna was coupled on at one turn off of ground of a six-turn coil.

[fol. 580] To my knowledge, the antenna was not only connected in this manner, it was connected both with one end grounded to the set and one end open.

Tests were made on this antenna with one of the lower wires connected to one turn of a six-turn coil. The other end was left open in some tests and in still further tests, it was grounded to the receiver set frame.

Mr. Darby: I offer in evidence copy of the file wrapper of the first Carter patent in suit, No. 1,623,196.

(Marked Defendant's Exhibit RR.)

Mr. Darby: I offer in evidence copy of the file wrapper of the second Carter patent, No. 1,909,610.

(Marked Defendant's Exhibit SS in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the first Lindenblad patent in suit, No. 1,884,006.

(Marked Defendant's Exhibit TT in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the second Lindenblad patent in suit, No. 1,927,522.

(Marked Defendant's Exhibit UU in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the third Carter patent in suit, No. 1,974,387.

(Marked Defendant's Exhibit VV in evidence.)

[fol. 581] Mr. Darby: I offer in evidence certified copy of the file wrapper and contents of Carter patent 2,027,020.

(Marked Defendant's Exhibit WW in evidence.)

LEO A. KELLEY, recalled.

Direct examination.

By Mr. Darby:

The Witness: In referring to the Bruce exhibits and the Bruce testimony, I intend to refer only to Exhibit MM and Exhibit JJ. These are the only ones that I feel are pertinent.

These tests related to short wave directional receiving antennæ, but it is well known that the principles which apply to reception apply as well as to the transmission of radio signals and in this respect all of the antenna patents in suit mention this same thing. For example, in the first Lindenblad patent, page 1, line 1, where it states:

"This invention relates to antennas and more particularly to directional antennæ for the propagation or reception of short wave signals."

In the second Lindenblad patent, on page 2, line 123, wherein it states:

"The antenna is equally suitable both for transmission and reception, the energy in the latter case to be collected and converged into the transmission line without the necessity of an impedance matching device", and again in the third [fol. 582] Carter patent, page 2, line 149:

"It is also to be distinctly understood that the unit so far described is not only useful for radiation purposes in a transmitting arrangement, but may be utilized equally as well for reception. That is, the antenna system, according to the present invention is equally well suited for any type of radiant action, whether it be collection of radiation energy or the transmission thereof."

Referring now to Defendant's Exhibit MM, there is shown in the second diagram from the top a receiver, short wave receiver, which Mr. Bruce said was somewhat directional, composed of two electrically long linear conductors. In this figure they are labeled two and a quarter wave lengths long, open ended, and inclined to each other at an angle.

If, in accordance with the teachings of these three patents in suit and what is generally understood in the art

anyway, the receiver marked R may be replaced by a transmitter, in which case the two electrically long wires inclined to each other, being open-ended, will be excited in phase opposition with standing waves. Therefore, if the first and second Lindenblad patents teach, that is, the second Lindenblad patent with particular reference to Fig. 2, teach what defendant is practicing, then their teaching in this respect is the same as Bruce has shown in this Exhibit MM.

Going to the third Carter patent, if I recall correctly, Mr. Hogan stated that the third Carter patent was distinguished [fol. 583] over the second Lindenblad patent in that, in the third Carter patent there was a rule given relating the electrical length of the sides of the V to the angle along the XX axis, as the patent puts it. And in that case I might refer to a passage in the patent on page 2, line 102, where it states:

"The angle alpha," alpha being the angle derived from the Abraham formula, "The angle alpha is the angle made by one of the conductors with the XX axis along which it is desired that the radiators AB propagate energy."

Now, Mr. Bruce, as a result of these early experiments, appreciated, so he testified, that there was some relationship between the length of the wires and their divergence. In order to get optimum results he devised a rule of thumb which is contained on Defendant's Exhibit JJ, to which I will now refer, this exhibit showing the Bruce rule relating the length of the wire to the angle of inclination.

Exhibit JJ was deduced by him some four months after the beginning of these tests as shown by the exhibits produced.

On this exhibit I find a number of lines which are tilted to the horizontal. These lines represent the various examples of the rule which Bruce was here setting forth, that rule being that for optimum results in the direction of the horizontal as here shown, these waves coming from the right, that the length of that wire should be one-half wave length longer than its projection on the horizontal, that is to say, on the direction in which the desired radiation was being received.

[fol. 584] The horizontal line that is shaded in this figure is marked "ground" at the right hand end. Mr. Bruce stated that he here meant perfect ground, so that the exhibit shows the relationship for optimum reception between the

inclined wire and its image in the ground, the optimum wave direction, the direction in which it was expected to receive best results, being on the bisector of that angle, in other words, as shown in this figure, parallel to the surface of the perfect ground.

Here is a definite teaching relating the electrical length of one side of a V-shaped antenna to the angle of the bisector for optimum results.

I have plotted the relationship which is given in the Bruce rule in the form shown in Exhibit JJ in a comparable form on a chart which included Fig. 12 of the third Carter patent. That is Exhibit W.

Referring to Exhibit W, the curve marked "Bruce angle" is the one which I plotted on this figure. The procedure for doing this was merely to use an obvious trigonometric relationship between the length of the wire and its projection on the bisector. The ratio of those two is simply the cosine of the angle. Consequently, one may plot the angle against the electrical length of the side by recognizing this simple trigonometric relationship.

Another way in which it might have been done would be to take the curves as actually shown by Bruce on that chart, and measure the angle and plot them against the length.

Referring again to the interchangeability of a transmitter and a receiver, Bruce, on Exhibit JJ, was showing the relationship for a receiver, but it is clear that this is [fol. 585] equally true of the transmitter; in other words, using Bruce's rule and a transmitter, one will obtain predominant radiation along the bisector of the angle between the wire and its image. It will be observed, on comparing the two, that is, comparing the curve on the Bruce angle, Exhibit W, with the curve specified by Carter derived from the Abraham formula, that they do not coincide.

Bruce's rule, it must be remembered, was a rule of thumb and was not derived by means of the Abraham formula, and it would not, therefore, be expected that it would coincide. The difference is not very great as can easily be seen on the figure. That is, for instance, at a length of four wave lengths there is a difference of about four degrees, and say at eight wave lengths there is a difference of about two to two and one-half degrees, and so forth.

Another thing is true: If one compares the predominant radiation obtained by using Bruce's angle with the pre-

dominant radiation also in the same direction using the angle specified by Carter, that in the latter case the radiation in that predominant direction will be somewhat greater. That is clear, of course, because that angle is derived from the Abraham formula and it is more rigorous than the rule of thumb method devised by Bruce.

Therefore, what is taught by the third Carter patent, as distinguished from the first two Lindenblad patents is also taught by Bruce, namely, this relationship between the length of the sides and the angle to the bisector between the wire and its image or the wire and the other side of the V. [fol. 586] I have plotted the wire and its image, and I have stated that an antenna wire over perfect ground will cooperate with its image in the ground and if, for example, it is an inclined wire, then the radiation sent out by the combination of that inclined wire and its image in the ground, the radiation above the ground is exactly the same as would be obtained from two wires, one wire for the wire that was inclined above the ground and the other wire replacing the image; the two wires being excited in phase opposition and inclined with respect to each other in the same manner as the wire and its image.

In confirmation of this I wish to read a letter which appears to have been written by Mr. Lindenblad and which is contained in the File Wrapper of the second Lindenblad patent. It is so pertinent that I intend to read it in full.

Q. 1818. You have made a statement as to image, and your opinion on it. Now proceed from that point.

A. I wish to conclude that therefore, that Exhibit JJ, which shows the inclined wire above perfect ground, gives the Bruce rule and applies equally well to the wires having a V, removing the ground; that is all.

Cross-examination.

By Mr. Blackmar:

X Q. 1820. Referring to Defendant's Exhibit JJ, am I correct in understanding you that you understand the wire length in this case is derived by making the wire a half a wave length longer than the projection of that wire on the direction of expected signal?

A. Well, in this figure—no, not exactly—in this figure, the one to which I refer, Exhibit JJ, this wire is inclined to the

[fol. 587] horizontal, the horizontal here being perfect ground, and the wave direction, that is, the desired wave direction, being in the direction of that surface of the horizontal ground.

X Q. 1821. And did you not state in your direct examination that the wires were to be a half a wave length longer than their projection on the direction of the expected received signal?

A. Yes, sir, I probably did.

X Q. 1822. If the ground in this Defendant's Exhibit JJ were imperfect ground, practical ground, would the actual direction of incoming wave accord with the arrow labeled wave direction?

A. No; if you assumed imperfect ground, the arrow marked wave direction would probably not be or would not be in the direction shown there.

X Q. 1823. In general, what would be its direction?

A. It would be inclined at an angle downward, depending, of course, on the imperfection of the soil.

X Q. 1824. And then, under those circumstances, the wave direction would, as I understand it, run downward from the right to the left on this sheet Defendant's JJ, is that correct?

A. Yes, sir, that is correct, if you assume imperfect ground.

X Q. 1825. And in that case what would the angle between the wire and the horizontal be if its length were a half a wave length longer than its projection on the wave direction?

A. Assuming imperfect ground, that wire would be at a slightly wider angle, depending, of course, on the difference in wave direction.

X Q. 1826. That is the angle between the wire and the horizontal would be wider?

A. That is correct.

[fol. 588] X Q. 1827. In the case that I have been considering, namely, practical ground, where would the image of the wire be?

A. If you assumed perfect ground, the image of the wire will be, the optical image—that is, its position where the optical image would be if the surface of the earth were an optical mirror.

X Q. 1828. And, of course, assuming imperfect ground, is assuming practical conditions, is it not?

A. Yes, sir, it is assuming practical conditions, but, if I may so add, this is a teaching of Bruce, and he does not take the ground into consideration. He is showing what the relationship should be between the wire and its image with perfect ground. He specifically pointed out that he meant perfect ground, and I am not referring to any practical applications of it, but merely to the theory, the rule, that was deduced by Bruce, and the application of which is clear.

X Q. 1829. Am I correct in understanding that that theory so deduced, namely, that the wire should be a half wave length longer than its projection on the wave direction, would apply equally to a single wire in space?

A. Yes, in exactly the same way that using the Abraham formula, a single wire in free space could be so inclined that the principal lobe of radiation, or its equivalent in reception, that is, it would be receptive in that direction in a similar manner.

X Q. 1830. With practical ground, actual ground, referring to Defendant's JJ, as I understand, you stated that the wire would be at a somewhat greater angle with the horizontal?

A. Yes, sir, that is right.

X Q. 1831. And that also applies to the image, am I to understand?

A. Yes, sir, that would also apply to the image.

[fol. 589] X Q. 1835. Considering practical ground, the angle between the wire and its image is twice that between the wire and the ground, on the horizontal, and that angle is greater by twice the amount of the difference between the wire over practical ground as compared with over perfect ground, is that correct?

A. If you mean that as you change the wire to a new angle, let us say a wider angle, that the distance traversed, the distance in angle traversed is also traversed by the image, so that twice the angle exists as before, that is, in moving the wire, the image also moves, so that a given angle movement in the wire also is accompanied by the same angle movement in the image, and therefore the difference is twice.

X Q. 1836. And if that were shown upon Defendant's Exhibit W, that is in the case of practical ground with respect to Defendant's Exhibit JJ, am I correct in under-

standing that the upper line now labeled "Bruce Angle," would be further away from the lower line?

A. If you make these assumptions and ignore the fact that Bruce shows perfect ground, you are correct, that it will be somewhere above the curve marked "Bruce Angle."

X Q. 1837. Will you please refer to Defendant's Exhibit MM, I think it is, the Bruce notes of May 14, 1926? You referred, I believe, to the second figure on the page where the wires are marked 2.24 lambda?

A. Yes, sir.

X Q. 1838. Have you calculated the angle between those wires?

A. No, sir, I have not.

Mr. Darby: The defendant rests.

[fol. 590] Rebuttal Proofs

PHILIP S. CARTER, called as a witness in behalf of the plaintiff in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I live in Port Jefferson, New York. My occupation is that of electrical engineer. I am employed by RCA Communications at Rocky Point Development Laboratories. I have been employed by the RCA and RCA Communications since 1920.

I am the patentee of the patent in suit, 1,974,387. The antenna that is disclosed in that patent that I have just mentioned is known as the Model D antenna. The idea of the Model D antenna was conceived some time prior to November, 1929. I fix the date of November, 1929, because I wrote a disclosure in a notebook at that time.

Q. 10. I hand you a notebook and three pages loose in the front of it, and ask you to point out in this notebook where the disclosure is found to which you have just referred?

A. These three pages are the original sheets removed from the notebook which I have in my hand, and in which

are carbon copies of the three original pages. This book is so made up that the originals can be removed for other use and the carbon copy is left for a permanent record in the book. Each page is made with a carbon. I have before me both the originals and carbons of those three pages that I am talking about.

These notes that are before me were written in that book on November 27, 1929. I wrote them myself. They are [fol. 591] in my handwriting throughout. I signed all three pages at the bottom, and all three pages were witnessed by Mr. H. E. Goldstine, on the same day. The date is November 27, 1929. Mr. Goldstine is an engineer who at that time was working with me on the antenna design and development.

He read the subject matter at the time he witnessed it, and I believe I explained the subject matter some time prior to writing these notes, as well as on the day that he witnessed them.

Q. 21. Would you state whether or not these three pages contain a disclosure in general form of the Model D antenna that is covered by the patent in suit known as the third Carter patent?

A. Yes, they do briefly describe the Model D antenna as described in the third Carter patent.

As to the disclosure that I made to Mr. Goldstine at the time I wrote those notes: the fundamental idea in this disclosure was a V arrangement of two wires, each being several wave lengths in length, and fed in phase opposition and arranged at the correct angle for their lengths in order to give maximum radiation in the direction of the bisector of the angle.

In addition to this fundamental unit, the disclosure related to several arrangements using the fundamental unit in order to increase the concentration of radiation both horizontally and vertically over that which would be obtained from a single unit.

Also it discloses an arrangement of two units, each of one or more V antennas, one located ahead of the other, along the line of the bisectors, the distance between the two units being an odd number of quarter wave lengths [fol. 592] and the two units being fed in proper quarter phase relation to give unidirectional radiation along the line of the bisector in one of the two directions in which it

was desired to radiate. What I have described in words is substantially the disclosure in the notebook.

I disclosed that idea of mine to somebody else at the time that I disclosed it to Mr. Goldstine. To the best of my recollection, I disclosed it, on the same day, to Mr. Hansell. That is the Mr. Hansell who has testified previously in this case. He was my superior during this work.

This letter which I have here was written by me on January 7, 1930, and addressed to Mr. C. H. Taylor, Vice-President in charge of engineering of RCA Communications. It concerns a patent disclosure which is attached and this patent disclosure covers this V type or Model D type antenna.

The building of this antenna was commenced some time, I believe, in December, and, at the time of the writing of this letter, it was under construction, as I stated in the letter. The photostatic copy of the letter which I have is one of an original letter written and signed by me. It was sent on January 7th. The disclosure of this invention which I just mentioned as being a patent disclosure, accompanied that letter to Mr. Taylor. This is a new disclosure which was written up for the Patent Department to use and make an application, and our standard procedure in all cases was to send these disclosures in to the vice-president in charge of engineering, for him to approve and send on to the patent department, if he wished.

Q. 35. Now, referring to the eight pages attached to your [fol. 593] letter of January 7th, to Mr. Taylor, what do you know about the origin of those pages and of the formula and diagrams that are included therein?

A. I will go through those pages in order to make certain that I will not make any mistake. On page 1, the figure was made by me and the typewriting copied from an original rough draft that I made myself, by our stenographer. On page 2, both of the figures were made by me. There are one or two notes written at right angles to the sheet which are not my writing. I believe they are Mr. Tunick's handwriting. (Mr. Tunick is our patent attorney handling this work.) The figure numbers are my handwriting. Page 3, the figure was made by me. All the writing on that page is mine with the exception of a note just above the apex of the V's, which is in Mr. Tunick's handwriting; that is, where it says "Leading odd number" something. On page

4, Fig. 5 was made by me with the exception of some of the letters pointing to some of the wires, which, I believe, were added later by Mr. Tunick. "Fig. 5" has been crossed out below the figure, and another figure, "Fig. 8", added. "Fig. 8" is not my handwriting, that is, the words "Fig. 8" written on the side after the original. The two little criss-cross figures at the right-hand upper corner of that page are not in my writing. Those labeled Fig. 10 and Fig. 10-A are not mine. I believe they were added later by Mr. Tunick. Going down the page, the figure originally labeled Fig. 6, with a line through it, was made by me, whereas the writing at the right of that, Fig. 9, I believe, is Mr. Tunick's handwriting, which he made after crossing out Fig. 6. The figure at the bottom of the page was made by me. The Fig. [fol. 594] 7 with a line through it is my writing, whereas Fig. 11 is not my writing. The writing in the corner, "Carter 4205", is not my writing. I believe it is Mr. Tunick's. On page 5, Fig. 8 was made by me. Figs. 9 and 10 were also made by me, and all writing on this page with the exception of a note just under the last line of typewriting are in my handwriting. That note, I believe, is in the stenographer's handwriting. On page 6 all the written material is in my handwriting with the exception of a note on the right-hand margin, which reads: "Gives rad." In something "direct" —I don't know what it means—direction. I believe that is Mr. Tunick's note there. I might also add with the exception of Mr. Tunick's signature on the bottom of the page, which, of course, is in his handwriting. Referring to the bottom of the page, that is my signature.

I signed that on January 4, 1930.

On page 7 both the figures were made by me, and all printing and handwriting on that page are mine with the exception of Mr. Harry Tunick's signature. This page bears my signature and was made on December 7, 1929. The figures on that page were made by me either on December 7, 1929, or prior to that date.

On page 8 all printing and handwriting are mine, and I made the curve and figure shown on this page. This curve was made on or prior to November 29, 1929. The date that is on this page is in my handwriting. That is my lettering of my name and my initials to the right. There is one note, small note, in the right hand margin near the top which is not my handwriting, I believe it is Mr. Tunick's, where it

[fol. 595] says Figure 12. Also Mr. Tunick's signature at the bottom of the page is not my handwriting.

Speaking generally of these pages 1 to 8, they are the pages which were attached to and sent with my letter of January 7th to Mr. Taylor.

This letter was written by me on May 9, 1930, signed by me on the same date, and sent to Mr. Harry Tunick of our Patent Department on that date. Accompanying this letter were a few sheets containing a little more detailed explanation concerning some points in the form of the disclosure sent in Mr. Taylor's letter. The three sheets which follow my letter of May 9, 1930, and attached thereto were the sheets that were sent with that letter. Those sheets were made up on or prior to May 8, 1930. That is my signature to these additional sheets.

The first paragraph of my letter of May 9, 1930, reads:

"Due to the pressure of other work mostly in connection with tests and adjustments of the antenna system covered by the above document, I have been delayed in the writing of a more detailed outline of the principles involved in this system."

As of the date of this letter, the antenna had been constructed, had gone through its initial adjustments, had been used for local tests, and the first series of long distance tests between Rocky Point and our receiving station at Marshall, California, had been completed; so that at that time we had reached our decision as to the relative merits of this antenna.

The nature of the first tests prior to the date of this letter were tests made in conjunction with adjusting the an- [fol. 596] tenna in the field in order to give what we expected to get out of it, locally. I think they were started toward the latter part of February and were completed some time during the following months.

Then the test to Marshall, Cal., the long distance test, was started toward the last of April. This antenna was directed on Marshall for this particular purpose. The test to Marshall was conducted during the early part of 1930. In those tests, we had a transmitter located in our development building at Rocky Point; we had this so-called model D antenna connected to one transmission line, running into the building; to another transmission line we had a half wave di-pole connected, and it was of the same mean

height as the model D antenna, and then we had switches provided near the transmitter in the building, so that we could very quickly switch from one antenna to the other. During these tests we switched back and forth between the two antennas, usually at the end of every five minutes.

At the beginning of a five minute period, we sent a message to Marshall giving the number of the particular test, and then proceeded to hold a long dash on the transmitter for them to make measurements. This was done so that the people measuring at Marshall would not know which antenna they were listening to. That would iron out any psychological effect on the operators out there that might come into the test. We wanted the people who were receiving at the other end not to know which of the two transmitters was sending. To keep them from getting onto the order and then knowing, we switched that order quite often. Sometimes we would run the same antenna two five minute [fol. 597] periods in succession without them knowing it, of course, and simply identifying the periods by numbers.

I have referred to this antenna that was constructed early in 1930, and on which we ran the tests just referred to, simply as a model D. This particular antenna consisted of four V wire units. There were two sections, one located behind the other, and in each of those sections, there were two V units, one above the other, separated by a half a wave length. These were built on 80 foot poles. The wires were eight wave lengths long, and the angle was 35 degrees between the wires of a single V and the spacing between the forward and after units was two and a quarter wave lengths. They were fed in phase opposition in a way which is mentioned in the disclosures.

That is the antenna I was talking about as having been constructed and tested in my previous testimony.

This next letter in this file is a letter from Mr. Harry Tunick to me, dated May 14, 1930. It is simply to the effect that he is forwarding me a rough draft of United States patent application papers, covering the V type antenna, which I have been discussing. Then follow a number of pages which are entitled "Docket No. 4205," concluding with two sheets of drawings, all marked "Docket 4205"; these are the sheets which were attached to his letter, and they contain the rough draft of the patent application as he submitted it to me. I received that letter

with that rough draft within a day or two after the date of his letter.

The next letter in the file is a letter from me to Mr. Tunick, dated May 20, 1930, and was written in answer to the letter which we just mentioned. It contains several com-
[fol. 598] ments I made upon the rough draft of the specification that was sent by Mr. Tunick, and some suggestions for changes. I signed and sent that letter on or about May 20th, the date it bears. That is my signature on page 2.

The next paper in the file, dated May 24, 1930, is a letter from Mr. Tunick to me, simply to the effect that he is sending me the final application papers covering this invention, that is, the V type antenna system. I received that letter with the final form of application on or about May 24th.

The next letter was written by me to Mr. Harry Tunick, and it is a letter sent with the patent application papers after having been signed by me, that is, the patent application papers were sent by me, forwarded with this letter. That is the letter with which I returned the executed application.

Mr. Brown: If your Honor please, I would like to offer as a single exhibit, Plaintiff's Exhibit 43, the file of papers that have been referred to by the witness, consisting of:

Letter of January 8, 1930, from Taylor to Grover.

Letter of January 7, 1930, from Carter to Taylor, with the attached patent disclosure as referred to by the witness.

Letter of April 1, 1930, from Tunick to the Patent Department.

Letter of May 9, 1930, from Carter to Tunick, with three attached sheets signed by the witness and referred to in his testimony.

Letter of May 14, 1930, from Tunick to Carter, with an attached rough draft of his specifications and claims and drawings in sketch.

[fol. 599] Letter of May 20, 1930, from Carter to Tunick.

Letter of May 24, 1930, from Tunick to Carter.

Letter of June 5, 1930, from Carter to Tunick.

(Marked Plaintiff's Exhibit 43 in evidence.)

The Witness: I have referred to certain tests of this Model D antenna working with Marshall, California; I made a written report of these tests and of the performance of that antenna as observed by me during the early part

of 1930; along the early part of May, 1930, I made a report covering the first few days of tests with Marshall. This is the report I made at that time. This report was given to Mr. Hansell, who was in charge of our work at Rocky Point at that time, to do with as he wished. This report was made by me; the drawings were made by me. That is my signature at the end of the report. It was signed May 6, 1930. I recognize that as a copy of a report I handed to Mr. Hansell on or about that date.

In all three of these charts attached to this report, the diagrams show the received signal strength at Marshall in decibels above one microvolt per meter as a reference level. In each one there are two curves, one being the received signal intensity for the horizontal half wave di-pole, and the other being the signal from the new type V antenna. They show the relative gain of one antenna over the other. These graphs show a very successful performance of this Model D antenna as compared to the half wave di-pole. In fact, at the top of two or three of these tests the power [fol. 600] ratio at the receiving station runs from 59.5 up to as high as 83.2, that is, the signal from the V antenna was in the latter case 83.2 times as strong as that from the half wave di-pole.

The first test chart is dated April 25, 1930, the last one was May 1, 1930; the others all lie in between those two dates.

As a result of the performance of this Model D test antenna, as recorded on those charts, I made, along with this report, a recommendation that this new type of antenna be substituted in place of several antennas which we had on schedule at that time for new construction. That recommendation is contained in the last three paragraphs with a heading "Recommendation" in this report.

The report was made on or prior to May 6, 1930.

Mr. Brown: I offer in evidence as a plaintiff's exhibit, the report entitled "Transmission Tests Model D Projector" just referred to by the witness.

(Marked Plaintiff's Exhibit 44 in evidence.)

The Witness: You hand me a copy of a letter dated March 22, 1930; this is a letter written by me and addressed to Mr. H. B. Morris, who was then in charge of the construction work at Rocky Point. The subject at the head of the

letter was: "Experimental antenna, new type." To the best of my recollection, at the time of the writing of this letter, we were already making the first tests and adjustments, on this V-type antenna; and this letter was written to Mr. Morris thanking him for the cooperation which his division had been giving us in getting this antenna con-
[fol. 601] structed, and so forth. This letter indicates that prior to its date the antenna had been completed. The date is March 22, 1930. The letter indicates that the antenna has been constructed. It so states in the letter. That is my signature. I wrote, signed and sent that letter on or about March 22, 1930.

Mr. Brown: I offer this letter in evidence.

(Marked Plaintiff's Exhibit 45 in evidence.)

Mr. Brown: I offer in evidence as a plaintiff's exhibit a photostatic copy of the three pages from the Carter notebook dated November 27, 1929, referred to by the witness in his examination.

(Marked Plaintiff's Exhibit 46 in evidence.)

Cross-examination.

By Mr. Darby:

The Witness: With respect to all of the statements contained in the letters, reports or memoranda that I testified about in my direct examination, and contained in Plaintiff's Exhibits 43 to 46 inclusive. I believe they correctly stated the facts and my beliefs at the time that I wrote them, with the exception of one possible, one or two possible minor errors which were corrected in a later letter. You ask me to point out the errors. In the original disclosure, attached to the letter to Mr. Taylor, the vice-president in charge of engineering, and dated January 7, 1930, there is an error in the formula on page 6. Under the radical there, where I have "cosine theta one," it should have read "sine theta
[fol. 602] one", but that was corrected later in the sheets attached to the letter to Mr. Tunick, dated May 9th, and I believe that the formula there at the top of page 7 is correct. That is the only error which I know of right now. There might be others. That formula was copied from my orig-

inal disclosure and that error was simply a mistake in copying. I thought I had copied it correctly, but I had not.

With that exception, I think that everything stated in these letters or reports or memoranda that I wrote, correctly expressed my belief at the time they were written.

The antennæ we constructed were erected on 80 foot poles.

They were the standard size poles obtainable; we had a large number of those poles at Rocky Point; we had been using them before that. They are the standard size for telegraph poles. I believe you are right in stating that the longer-sized poles come from the West Coast; for that reason an 80 foot pole is what is ordinarily used here in the East, because of the expense incident to getting taller poles.

In my letter of May 9, 1930, to Mr. Tunick, the three sheets, numbered pages 5, 6 and 7, are, to the best of my knowledge, the only sheets that were transmitted with that letter. I believe there were no sheets numbered 1 to 4, inclusive. The intention was to substitute these three sheets in place of the former three sheets which had been sent in with the original disclosure—explaining the same thing. I went into a little more detail here and made the correction to the formula which I just mentioned.

[fol. 603] With respect to the figures or drawings in the various sheets and papers that I testified about and made at that time. I certainly think those figures and drawings correctly represent what I intended them to represent at the time that they were made. That is, it was my belief at the time that they were made, that they were correct representations.

X Q. 118. With reference to Mr. Tunick's letter to you of May 14, 1930, where he sent you the draft specification, a copy of which draft is attached to Mr. Tunick's letter to you, is the draft as it now is in the same condition as it was when you received it from Mr. Tunick? That is, did you make any corrections to the draft yourself?

A. I am not certain without looking it over very carefully. Most of these corrections are in Mr. Tunick's writing. In going over these in a hurry now, I haven't found any correction I recognize as my writing. I believe that I received this draft from Mr. Tunick in exactly the condition as it is shown by these photostatic pages.

My purpose in going over this rough draft was to check it for accuracy, and to make suggestions of changes. I either changed it to conform with my idea or I accepted it in the form that Mr. Tunick had changed it. In its present condition, as represented by the photostatic copies, it was not entirely acceptable to me as correctly describing the invention that I believed I had made; in the following letter, which I believe you have there, dated May 20th, I wrote Mr. Tunick and mentioned several points which should have been changed. I went over the draft and simply wrote a letter concerning the changes.

[fol. 604] X Q. 126. I hand you the original draft of specification from which the photostats have been made, and will you please check over the red pencil notations on that draft so as to enable you to state whether or not they were all made by you?

A. Yes, all the writing in the red pencil is mine.

Mr. Brown: Suppose we just later take the copy of Plaintiff's Exhibit 43 which is in evidence and underline it in red to indicate that which was written in red.

Mr. Darby: That will be entirely agreeable.

The Court: If you will just indicate on the copy that is in evidence what was in red, that is all that the difference is, then there is no necessity for having the original.

CLARENCE W. HANSELL, recalled in behalf of the plaintiff, in rebuttal, further testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I am the same C. W. Hansell who has testified in this case.

I will tell you what I know about the origin of the Model D antenna, that is my own direct knowledge about it, during the period from late 1929 through up to May of 1930: During the latter part of 1929, Mr. P. S. Carter was engaged under my general direction in the design of antennas for commercial service, and, whenever time would permit, in calculations aiming at determining the characteristics of

other types of antennas than those which we were using at that time.

[fol. 605] Some time in the last quarter of 1929, his calculations indicated that a V antenna of the type involved in this suit should be a very promising subject for development. His calculations indicated that the directivity would be very considerable.

He proposed to me that we set up a full-scale model with which we could make tests over a long distance to determine the effectiveness of that type of antenna.

It was evident to all of us at that time that if the antenna would give the amount of directivity which Carter predicted, it would be very much cheaper to build in respect to directivity per dollar than models which we had used previously.

Right at this time, I can't recall the specific date on which he disclosed it to me, but I do remember making arrangements for the expenditure of money necessary to build the antenna some time in the latter part of 1929. At that time, I was the head of the department in which Mr. Carter was working. It was necessary for me to make the arrangements for the erection of that antenna.

According to my recollection, the first part of the construction of the Model D antenna, embodying this new idea of Mr. Carter's, was begun probably in December of 1929, and continued until about March, 1930. I know about the testing of that antenna. In some of the very first tests made locally on the antenna, I assisted personally, and then, a little later when we were making tests, between Rocky Point and Marshall, California, I, of course, kept myself familiar with the tests, and on some occasions, personally operated the transmitter used in the tests. I heard [fol. 606] Mr. Carter testify that these tests were made in April; that accords with my recollection.

This letter dated March 21, 1930, bears my signature at the bottom. That letter was written, signed and sent by me on or about the date that it bears. This letter states that we had completed the construction of what I called our modified type horizontally polarized harmonic antenna, which was suggested by Mr. P. S. Carter; the antenna that I referred to there is what we now know as the Model D, which was this V-type antenna involved in this suit. It

shows the antenna had been constructed before that date of March 21, 1930.

You show me a carbon of a letter, dated March 31, 1930; this is a copy of a letter sent by Mr. R. R. Beal, manager of the Pacific Division, to Mr. C. H. Taylor, vice-president in charge of engineering, advising that the receiving station at Marshall would be in a position to make the measurements on this antenna, which we had requested. This is a photostat of the copy which was sent directly to me by Mr. Beal at that time. I received the original shortly after March 31, 1930.

I actually saw this Model D antenna that was built early in 1930. This was the only antenna at Rocky Point of a construction that could possibly have been referred to by the description Model D antenna during that period.

This letter, of which you hand me a copy, was written by me on May 7, 1930, to Mr. H. H. Beverage, Chief Engineer, for the purpose of transmitting Carter's report and results of the first series of tests made on this Model D antenna. Mr. Carter's report was dated May 6, 1930, and is part of Plaintiff's Exhibit 44. That is my signature on that letter. [fol. 607] I wrote, signed and sent that letter on or about the date it bears. The original of that letter was sent to Mr. H. H. Beverage, and I was so proud of the results of this test that I sent out a large number of copies, as indicated on the original letter. One was sent to Mr. C. H. Taylor, vice-president in charge of engineering, and an extra copy to Mr. Beverage. There was a copy sent to Mr. J. H. Shannon, who was at that time in charge of lay-out and station design, and a copy to Mr. Hallborg, engineer in our New York office, and one copy to Mr. Carter and one to Mr. Tunick of the Patent Department. Mr. Beverage is my next superior in the organization of RCA Communications.

The results on which Carter's report was based and the report itself, which was sent with my letter, indicates that this antenna was more satisfactory than any model we had had available up to that time, and that it should be used for all new construction.

Mr. Brown: I now offer in evidence letter dated May 7, 1930, to Mr. Beverage.

(Marked Plaintiff's Exhibit 47 in evidence.)

Mr. Brown: I also offer in evidence at this time, as a plaintiff's exhibit, a letter of Hansell to Beverage, dated March 21, 1930, and frequently referred to.

(Marked Plaintiff's Exhibit 48 in evidence.)

According to my recollection, the Model D antenna, as I have stated I saw it early in 1930, was made up of a com-
[fol. 608] bination of four V type radiators. Each element of the antenna, that is, if we divide the antenna into two general parts, was made up of two V's, each V a number of wave lengths long and fed with currents in phase opposition, set at an angle of 35 degrees.

Two V's in each element were mounted one above the other at a distance of one-half a wave length and excited co-phasially, and behind that combination was another combination of two V's spaced along the general direction of the bisector a distance of nine one-quarter wave lengths and the two elements were then excited in phase quadrature to give a unidirectional beam of radiation out in the general direction of the bisector from the apices toward the open ends of the V's. Observations were made on the North Star, by which the antenna was laid out in a direction on the Great Circle Path to Marshall. By that I mean that the line of the bisector of the V's of this antenna pointed in the Great Circle direction of Marshall.

When I said "angle of 35 degrees," I meant the angle between the two wires of each V was 35 degrees, corresponding to a half angle of 17½.

I was thoroughly familiar with this antenna at that time.

Each V unit of that antenna was in a horizontal plane.

Mr. Darby: No cross-examination.

[fol. 609] HALLAN GOLDSTINE, called as a witness on behalf of the plaintiff, in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I live at Port Jefferson Station, New York. I am working as a radio engineer for RCA Communications.

I am a graduate mechanical engineer, University of Kentucky. I have been working for RCA Communications since about October, 1928, at Rocky Point. I came with the company first of July, 1928.

During the time I have been with RCA Communications, I worked with Mr. P. S. Carter for quite a period,—the last part of 1929 and first part of 1930. I am familiar with what was known during early in 1930, as Model D antenna at Rocky Point.

Plaintiff's Exhibit 46 consists of three pages from Mr. Carter's notebook which I witnessed and signed. I first saw those three pages or the originals thereof on the date given here,—November 27, 1929. That is my signature on the bottoms of the three pages. I wrote that signature on those pages on the date given here, on November 27, 1929. As to why I wrote my name on those pages: Mr. Carter gave me these, in his notebook, and explained the operation of this antenna, and I read this disclosure given here, and, reading it and understanding it, I signed it to witness the fact that I had understood it.

Shortly after this date a Model D antenna was constructed near the experimental building. I helped Mr. Carter adjust and make measurements locally on this antenna, and [fol. 610] then, at a later date, I think it was some time in April, around the first part of April, and during April we ran some tests to Marshall, California, and I took care of the transmitter on those tests. We had two antennas, this one, the Model D, and another antenna, and we would send out signals to Marshall. Before each transmission we would give an identifying number so that we could tell which test it was by the number given, so that they wouldn't know which antenna was on, but we could identify them by the number; and then we would leave the transmitter on a steady dash for the rest of that period of five minutes, and then we would change over to the other antenna and continue that throughout the day, and we received messages back from them that they had received the readings, and I helped calculate and plot some of those readings. I can send and receive telegraph code. I actually sent the test messages to Marshall; I took care of that; for each transmission we would have to send an identifying number.

Mr. Darby: No cross-examination.

HARRY TUNICK, called as a witness on behalf of the plaintiff, in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I reside at Rye, New York; my occupation is that of attorney. I am employed by the plaintiff as Division Patent Attorney in their Patent Department. I have been an attorney in the Patent Department since 1926, and [fol. 611] Division Attorney since 1932. I was an attorney in the Patent Department of the Radio Corporation in January, 1930. That continued until after June of 1930.

You hand me Plaintiff's Exhibit 43 in this case: I recognize the signature of Mr. C. H. Taylor on a letter addressed to Mr. H. G. Grover, the letter being dated January 8, 1930. Mr. Grover was the patent attorney for the Radio Corporation. I was one of his assistants.

I know that it is the custom of the Patent Department to stamp all letters on the date that they are received, and according to the Patent Department's stamp, this letter was received on January 9, 1930. In the upper left hand corner of the letter there is a pencil note to Mr. Carlson, initialed H. G. I recognize the writing to be that of Mr. Grover. That note asks Mr. Carlson to please acknowledge and docket for Mr. Tunick. I am the Mr. Tunick there referred to. Pursuant to that note, that letter and the enclosures with it came to me some time on or before January 16, 1930. As these disclosures came to me, and after I had read them, it was my custom, and still is, to sign them and date them as of the time of reading them. I signed and dated that particular disclosure on January 16, 1930. That is my signature at the foot of it.

Having examined that, I can state that at that time I had read and understood that disclosure as of that date. I know that to be a fact for the reason that up to that time I had been in charge of the patent application work relating, among other things, to antennas.

At this time I handled all of the patent application work originating at Rocky Point, and it was my custom to make [fol. 612] trips out there carrying various dockets in order to discuss them with the engineers from various viewpoints. Apparently, according to the letter dated April 1, 1930, which I dictated on that date and which I signed on that

date and which forms part of this Exhibit, I had been out to Rocky Point and discussed the disclosure with Mr. Carter. I recall asking Mr. Carter to let me have the equation for the curve appearing on sheet No. 8 of this Exhibit, which I signed on January 16, 1930. I believe subsequent correspondence will show that Mr. Carter furnished me with that equation.

On May 10, 1930, I had witnessed, after reading and understanding both a letter of May 9th, 1930, sent to me by Mr. Carter, and attached to that letter were some sheets which I also witnessed and dated and understood, as of May 10, 1930. On sheet No. 6 there is given an empirical formula reading: Alpha equals 50.9 (1 over lambda) to the minus 0.513 degrees. This I understood to be the equation for the curve given with the original disclosure to the patent department, which I have referred to as sheet No. 8, and which is entitled, "Correct angle", and witnessed by me on January 16, 1930.

Some time before May 14, 1930, I prepared a rough draft of the patent application covering Mr. Carter's invention as described in the original disclosure sent to the Patent Department some time in the early part of January. It was received in the Patent Department on January 9, 1930. The rough draft had been dictated some time before May 14, 1930, and revised in pencil by me and sent out on May 14, 1930, to Mr. Carter.

[fol. 613] This rough draft which is contained in this file has a number of pencil changes thereon, which Mr. Carter has said are in my handwriting. These changes were made before this draft was sent to Mr. Carter. There is no substantial change in the specification and claims as I drew them from the disclosure of January of 1930.

I notice that on May 21st we received at the Patent Department an additional letter from Mr. Carter returning his rough draft. I added portions of this letter to the original rough draft, as indicated by the remarks "Insert 1", "Insert 2", "Insert 3", on page 1 of that letter, and "Insert 4", on page 2 of that letter. I believe these inserts added somewhat to the material already in the original rough draft. Now, with the inserts made, on May 21st, I find that I sent to Mr. Carter a final draft for him to execute. I also enclosed a check for one dollar which covered the nominal consideration for assigning this case to the Radio Corporation. On June 6th, I received another letter from Mr.

Carter enclosing the executed patent application. This application was filed in the Patent Office June 11, 1930, and given Serial No. 460,467 and resulted in the third Carter patent in suit, No. 1,974,387.

The letters which appear in that file were written, signed and sent by me on or about the dates that appear thereon. And the letters addressed to me from Mr. Carter were received by me on or shortly after the dates that they bear.

On most of the documents in that file, the notation "Docket No. 4205" appears; that indicates the folder number in which Mr. Carter's invention was placed. It is the Patent [fol. 614] Department reference number. In other words, it is the file number under which correspondence, and so forth, would be filed.

Cross-examination.

By Mr. Darby:

The Witness: A division attorney has charge of a group of attorneys. That is, he has charge of a division of attorneys. I may add that in the division that I have charge of that deals mainly with those inventions lying in the field of radio communication, long-distance communication.

It is my custom and has been, and the instance concerning which I have testified was no exception, to study a disclosure, read it and understand it, before I sign it. So that every one of these documents that I witnessed, that is, bearing on this Carter invention, every one that I witnessed I understood before I signed. The understanding that I obtained from these disclosures to me was reflected in this draft specification that I sent to Mr. Carter; it was fully and accurately and completely reflected therein.

Mr. Blackmar: I offer in evidence Plaintiff's Exhibit 34 for Identification and also Plaintiff's Exhibit 36 for Identification, both being sketches which were referred to by the witness Kelley in the course of his cross-examination.

(Marked Plaintiff's Exhibits 34 and 36, respectively, in evidence.)

Mr. Brown: Mr. Darby offered in evidence a certified copy of the File Wrapper and contents of Carter patent 2,027,020. [fol. 615] You may remember I raised the question of the purpose, and Mr. Darby answered that they were offered to

show estoppel. He offered an additional file history of a patent not in suit, a later patent to Carter, and if your Honor please, I wish now to object to that Exhibit WW, the file history of patent 2,027,020, and to move to strike it out as being irrelevant, immaterial and incompetent to any issue in this case.

The Court: Well, I will take it. I will see whether it is admissible for any purpose. If it is, I will consider it in, and if I do not think it is admissible, I won't.

JOHN V. L. HOGAN, recalled in behalf of the plaintiff in rebuttal, further testified as follows:

Direct examination.

By Mr. Blackmar:

Q. 935. Please refer to the Brown British patent, No. 14,449: does this patent disclose or teach the use as radiating elements of an antenna of wires several wave lengths long?

A. No. Fig. 1 of the Brown patent, for example, shows a spark transmitter, and such a spark exciter will cause the vertical wires to oscillate at their fundamental frequency, that is to say, they will be fundamentally excited in this transmitter, and thus the wires would each be one-quarter wave length long.

Q. 938. Is it possible to secure, with the system shown in this patent, directivity that is comparable to that which can be secured with Lindenblad's long wires, referring par-
[fol. 616] ticularly to the first Lindenblad patent?

A. No, it is not. With short wires, one would have to use a multiplicity of radiators or antenna sections, and they would have to be lined up and phased in order to give high directivity. The arrangement illustrated in Brown would not give high directivity.

Q. 939. Were systems in which antennas of the type shown in Brown, the general type shown in Brown, used in multiple or in arrays, in practical use in the art, prior to 1928?

A. Yes, if we assume Brown to have shown the equivalent of half wave di-poles, for example, a multiplicity or array of short wires like that is the basis of the British beam di-

rective antenna or the model A directive antenna or of other curtain types of directive antennas.

Q. 940. Please refer to the Levy French patent, No. 593,570 and the patent of addition thereto, No. 30,798: first referring to the patent of addition, do you find anything indicated there, that indicates the length of the wires in Fig. 1 thereof?

A. Yes. In the first paragraph of the patent of addition, Levy says that modifications of the arrangements shown in the parent patent may be made and that, for instance, wires 1 and 2 of the arrangement shown in the Fig. 1 of the parent patent, instead of being parallel in one direction, could form, between themselves, any desired angle. Then he says that Fig. 1 of the drawing of the patent of addition represents such an antenna. Referring to the original patent, Fig. 2 is a diagram which illustrates the distribution of current in the antenna of Fig. 1, that is to say, of Fig. 1 of the original patent, and also of Fig. 1 of the additional patent, which is simply Fig. 1 of the original, differently disposed. That Fig. 2 shows a quarter wave of [fol. 617] current on each of the two halves of the upper part of Fig. 1 antenna, and thus fixes the length of the entire span from pole to pole in Fig. 1 of the patent, as one-half wave or of the antenna as being made up of two quarter-wave wires.

Q. 943. What do you understand the teaching of Levy to be with respect to the angle between the net works 1 and 2 of Fig. 1 of the patent of addition?

A. That between the two sections, there is to be some angle less than 180 degrees, and as he says, particularly a right angle, that is to say, the only specified case is that of a right angle, but it says generally it may have any angle smaller than 180 degrees.

Q. 944. Please compare Levy's use of several parallel wires in each of his net works 1 and 2, as shown in Fig. 1 of the patent of addition, with Carter's use of several parallel wires in, for example, Figs. 4 and 5 and 11 of the third Carter patent?

A. Yes, in the Carter patent, the wires shown in Figs. 4 and 5 and 11 are carefully placed, one directly above the other, and one exactly like the one below it, and moreover, the energy to feed those wires is brought into a mid point end connection, symmetrically, so that the current in the two wires will be in the same phase and of the same amount

and both the wires will be placed and driven in a perfectly symmetrical way vertically. In that case, as I pointed out, the radiation measured in the horizontal plane will be of the same general form or the same as with single wires. The directivity, in which we are interested, toward a distant point on the earth's surface, from the horizontal antenna, is not changed.

[fol. 618] On the other hand, Levy has no careful provisions of that sort. The connections as shown in Fig. 1 of the patent of addition are at the corner of each of the two three wire systems, and I understand that the two three wire systems would lie in horizontal planes like the flat top which was common in antennas of the type used on board ship, and as I would gather further from the showing of Fig. 1 of the original patent.

Q. 945. As shown in Levy and in the third Carter patent, are these systems of parallel wires equivalent from the point of view of directional radiation?

A. No, I pointed out that Carter's arrangement is equivalent to a single V as far as the radiation in the horizontal plane, or measured in the horizontal plane, is concerned, but Levy's directive pattern, if there were one, would be uncertain because the phasing and the relative position of the wires are not definite.

Q. 946. Have you had prepared charts showing the directional characteristics of the net works of Levy's Fig. 1, patent of addition, at various angles?

A. No, I could not do that without knowing the phasing and the relative positions of the several wires.

Q. 947. Have you had charts prepared on the assumption of the use of single wires in place of Levy's net works?

A. Yes, I have had made up a small chart which is entitled, "Field Intensity Patterns of an Antenna Composed of Two Quarter Wave Length Wires at Various Angles."

The upper right hand corner of the chart shows the Figure 8 plot for the two quarter wave length wires at the 180 degree angle, that is to say, the di-pole arrangement corresponding to Fig. 1 of the original patent. And that, [fol. 619] of course, would be approximated if the angle were very close to 180 degrees in the case of the Fig. 1 of the patent of addition.

The figure at the upper left hand corner of this chart shows the directional pattern when the angle is reduced

to 135 degrees, and that comprises a figure which does not drop to zero in the perpendicular direction and has a somewhat reduced amplitude in the direction of the bisector.

The lower right hand corner shows the 90 degree case, which is specifically referred to in the specification of the patent of addition, and indicates a further reduction of the radiation in the direction of the bisector of the 90 degree angle, and also a symmetrical radiating pattern.

At the left of the lower part of the diagram, is the plot for the 45 degree angle, which is somewhat like that for the 135 degree angle, but still is smaller, indicating still less effective radiation.

The radii of each of these four plots in the direction of the bisector are based on unity for the 180 degree case, corresponding to the di-pole, and the assumption of a uniform loss of energy in the bisector direction as the wire is swung from 180 degrees to zero degrees.

Q. 949. Does that mean that all four diagrams on the page are drawn to the same scale, in effect?

A. Yes, to the same scale, and with the same power on that assumption, and that indicates that the best radiation is from the 180 degree case, and also the best ratio of radiation in the desired direction, to the direction perpendicular to that.

Mr. Blackmar: I offer the diagram referred to by Mr. Hogan in evidence.

(Marked Plaintiff's Exhibit 51 in evidence.)

[fol. 620] Q. 950. Does Levy teach what kind of directivity, if any, will be secured by the arrangement of his net works in accordance with Fig. 1 of his patent of addition, and as described therein?

A. No, he does not, so far as I can find.

Q. 951. Mr. Kelley was asked in Q. 479 (R. p. 361): "Will you compare the disclosure of these two French patents to Levy, that is, the original and the patent of addition, with the disclosure of the second Lindenblad patent?" And the answer was: "Again assuming that Fig. 2 of the second Lindenblad patent is for a standing wave antenna, then Fig. 1 of the Levy patent of addition is of course the same thing." Do you agree with that?

A. No, it is not the same thing.

Q. 953. Refer, please, to the Japanese patent to Takagishi:

does that patentee make clear to one skilled in the art what he proposes to do, and how he proposes to do it?

A. Yes, he proposes to use vertical antenna wires to radiate waves upward at a high angle; and he proposes to do that by staggering the ends of these vertical wires by an amount such that the angle of the stagger is equal to the desired upward angle of radiation. That is shown, for example, in Fig. 2, the upper left-hand figure of the drawings of the patent, where the ends of the wires are staggered and the direction of radiation is supposed to be along the line connecting the two ends of the wires.

Q. 954. Is there anything in the theory of this patentee that requires his wires to be more than a fraction of a wave length long?

A. No, there is not. Further, his own tests of his own invention used 40 meter waves with wires of various lengths, from 26 meters downward. These tests are described in [fol. 621] the patent itself. The longest wire that he used then would be 65 per cent. of the wave length in working out his own experiments.

Q. 955. Does this patentee depend for his supposed system upon the utilization of the principal lobes of radiation at an acute angle from his wires?

A. No, he does not.

Q. 956. With respect to each of the three antenna patents in suit, that is the first and second Lindenblad and the third Carter patent, do they depend in their principles of operation upon the principal radiation at an acute angle with the wires?

A. Yes, they do; each one of the three patents shows antennas which depend upon that type of radiation.

Q. 957. Does this Japanese patentee teach or suggest the use in his system of wires several wave lengths long or having several standing waves thereon at the operating frequencies?

A. No, so far as I can find in the text there is no such teaching, and in the illustrations, there is no wire shown that is more than a little over one wave length long. Each of Figs. 1 and 4 shows one wire with a little more than one complete wave on the wire.

Q. 958. Please take up the first Bethenod French patent, No. 596,737: what does Bethenod teach as to the length of the wires in his networks, designated 2 and 3 on Fig. 1 of the drawing?

A. There is no teaching that I can find as to the length

of the wires in either of the networks 2 and 3. Bethenod simply says that the fundamental wave length of the entire system, that is, from 2 down through the line to the generator and back up the line to 3 is lower than the trans-
[fol. 622] mission wave length in general. That would mean that the whole electrical length, from one of the networks through the system and back to the other would be less than one-half wave length. There is nothing stated as to the length of any part of that complete system nor specifically as to the length of the part comprised by the networks.

—. Please tell us what you understand by the statement in the Bethenod patent No. 596,737, that "the antenna thus constituted may be operated at the harmonic."

A. That statement appears at the beginning of the third paragraph on page 1 of the translation, and "the antenna thus constituted", I understand is the system which has been described in the preceding paragraph and which I have described in my earlier answer. That system, the specification says, "may be operated at the harmonic," and of course that means that that system may be operated at a frequency which is two or three or even more times the fundamental or low frequency of the system which is referred to in the first paragraph.

Q. 961. What does that indicate as to the length of the wires in the networks 2 and 3?

A. It doesn't indicate anything with respect to their length, because there is no statement of the proportion of the total electrical length of the entire system which is in the horizontal wires.

Q. 962. Are Bethenod's networks connected to high frequency apparatus at adjacent ends or excited at adjacent ends?

A. No, each of the two networks as shown in Fig. 2 is fed centrally, and at the center the currents in each of the net works will travel in opposite directions, that is, on each side of center.

[fol. 623] Q. 963. On page 3 of the translation, Bethenod refers to obtaining directional effects either in the horizontal plane or in the vertical plane or in both planes. Does he tell you how to incline his networks in order to secure any particular kind of directivity?

A. No, he makes only a perfectly general statement that the networks may be arranged vertically or even inclined

not only with respect to the ground but also with respect to one another. That general statement covers a multitude of cases, and does not single out any one of them for any particular purpose.

Q. 964. Do you agree with Mr. Kelley that with inclined arrangements such as suggested by Bethenod, the wires of one network may all be parallel with all of the wires of the other network?

A. Yes, that would occur in several of the cases included in the general statement of inclination.

Q. 965. Do you also agree with Mr. Kelley that this is a possible arrangement, and that there are quite a few possibilities within the description of Bethenod?

A. Yes.

Q. 966. Does Bethenod state or suggest in this patent that there is under any circumstances any particular angle between the wires of the networks or between his networks that would be desirable for any purpose?

A. No, he specifies no particular angle for any purpose, and neither does he specify any particular type of inclination which would show where any particular angle would be measured.

Q. 967. Referring to the Melton article in the August, 1926, issue of Q. S. T. Magazine, as I understand the defendant's position, it is that if Melton bent over one of his long vertical wires, which he says may be done, that wire, with its [fol. 624] image in the ground, becomes equivalent to two long parallel wires fed in phase opposition. Do you agree with this?

A. No. I do not agree, because in making that comparison, Mr. Kelley suggests a purely theoretical equivalent that can never be had in short wave practice. To do it, he must assume a theoretically perfect ground which never is found, so that he may have the true image which is required for the assumption of equivalence. Beyond that, he must compare the single wire and its assumed perfect image with the two wires, assumed to be in free space, whereas, the practical case puts the two wires always above an actual ground, consequently, even if one did assume the image theory to apply, as Mr. Kelley uses it, the two wires would also have their images in the ground, so that in effect they would be equivalent to a four-wire system, and consequently would be quite different from a single wire.

Q. 970. And what is the practical difference as to directivity between a single-wire antenna over actual ground and

the two-wire antenna, such as that of the first Lindenblad patent, also over actual ground?

A. The two-wire antenna will be more than twice as directive as a single-wire antenna, assuming the best conditions for each case.

Q. 971. May I ask you what you mean by "best conditions"?

A. Best conditions as to two wires in terms of spacing and stagger and with respect to the single wire, the best direction for its particular length and so forth.

Q. 972. What about their relative height above the ground?

A. You would assume the same heights of the centers of the systems.

[fol. 625] Q. 973. Now, will you please briefly explain why there is this difference in directivity?

A. Because the radiation in the desired direction from the two wires is made to add, which gives this substantial increase in the directivity over a single wire, and then to that is added the effect of reflection from the ground beyond the antenna system, to whatever extent that may exist over the particular ground. That same effect of reflection from the ground beyond the antenna is assumed to help out the radiation from a single wire to the same extent, but to no greater extent, so that the more than doubled directivity of the two long wires still determines the ratio of improvement of the two wires over one.

Q. 974. In this Melton article, is there any mention or suggestion of utilization of the effects of an image in the operation of his antenna?

A. No, there is not.

Q. 975. In fact, is there any mention of an image?

A. I can't find any.

Q. 976. Is there any suggestion that Melton considers his single wire as equivalent of two parallel wires?

A. No.

Q. 977. Please refer to Defendant's Exhibit JJ, which is the Bruce theoretical curve of September 28, 1926. Does that teach the use of a V antenna?

A. No; if anything it teaches the use of a single tilted wire.

Q. 978. Mr. Kelley stated, referring to this diagram (R. p. 584): "Here is a definite teaching relating the electrical length of one side of a V-shaped antenna to the angle of the bisector for optimum results." Do you agree with that?

A. No, I do not. I understand and believe that at the

most this diagram teaches the inclination of a single wire [fol. 626] to the direction of arriving waves for the best signal.

Q. 979. Do you understand the theory of the derivation of this curve?

A. Yes, I understand the basis of the Bruce rule, that is, that the projection of the wire on the direction of wave arrival shall be one-half wave length less than the length of the wire itself, so that the proper phase relation in the wire will be had.

Q. 980. Is the presence of ground or of an image necessary for the derivation of the Bruce rule, or rule of thumb, as Mr. Kelley has expressed it?

A. No, it is not necessary in any sense. The same rule would apply to a single wire in free space.

Q. 981. If such tilted wire were used in practice, would it be equivalent to a V antenna?

A. No.

Q. 982. Why not?

A. Because there is nothing to correspond to the other wire of the V. Mr. Kelley, in discussing one aspect of this, assumed the wire to be set up over theoretically perfect ground, and thereby found and assumed true image of the tilted wire. Then he took that image to be the second wire of a V. But that can never occur in short-wave practice, as I have explained, because there is no such thing as the perfect ground which he had to assume.

Q. 983. Mr. Bruce was asked, Q. 45 (R. p. 507), with respect to this sketch as follows: "On this sketch it is annotated that the ground is shown in the conventional character of lines as well as the word 'ground'. Will you state whether or not in making that sketch you considered actual ground or perfect ground?" And his answer to that question was as follows: "In a sketch of this type the important thing is the relation of the wire with the direction of the [fol. 627] wave. However, perfect ground is intended in this case to fit that assumption."

Do you consider what you have just stated to be consistent or inconsistent with Mr. Bruce's testimony?

A. What I have spoken of is a different effect of perfect ground and a different assumption, but Mr. Bruce is correct in saying that the assumption of perfect ground would correspond to the horizontal wave direction which he showed, and therefore the drawing of his line marked "ground" would give him a line at the base or left-hand end of the antenna wire upon which to draw his projection.

Q. 985. Now, to assume a theoretical case of perfect ground, is there any difference between a single tilted wire above the ground and a V antenna likewise above the ground?

A. Yes.

Q. 986. What is that difference?

A. The V antenna under those assumptions would have a complete V image below it, and thus form a four-wire double V system, including the image assumption.

Q. 987. Now, in practice, referring again to Defendant's Exhibit JJ, is the direction from which short waves are received horizontal, as indicated in this sketch?

A. No, in practice they have a wave front corresponding to arrival at angles from 10 degrees to as much as 20 degrees or more above the horizontal.

Q. 988. Now, applying Bruce's rule for optimum angle between the wire and assumed wave direction to the practical case of a wave coming in at an angle to the horizontal, would the angle of Bruce's wire to the ground, as shown in this Defendant's Exhibit JJ, be changed?

A. Yes. If we should assume that the wave direction were 10 or 20 degrees downward toward the earth, then following [fol. 628] Bruce's rule, which says that the projection of the wire on the direction of arrival of the waves is to be one-half wave length less than the length of the wire, the wire would have to be tilted so that its upper end was higher in the air, in other words, so that it made a greater angle with the ground, the angle of the wire from that shown for horizontal arrival being increased by the same angle of wave arrival direction, namely, the angle between the arrival of waves on the ground plane; in other words, following the Bruce rule, the wire would make a larger angle with the ground. In other words, it would be nearer the perpendicular.

Q. 991. What effect would that have as to the angle between the wire and its image, if there were an image?

A. Assuming that there were an image and that the wire were tilted up to a more nearly perpendicular position, the assumed image would tilt down correspondingly and the angle between the wire and the image would be correspondingly increased, the total angle being double the change made in the one wire.

Q. 992. If, then, we assume that there is an image and that therefore the Bruce wire represents a V antenna, how would

the angle between the legs of this supposed V and its bisector compare with the angle recommended by Carter in his third patent?

A. On those several assumptions the angle would be increased, as I have said. If the change in the wave direction above ground were 10 degrees, the Bruce angle would be raised by 10 degrees for each point corresponding to the length of the wire.

Q. 993. Will you please explain that with reference to Defendant's Exhibit W?

[fol. 629] A. Yes; it would mean under those assumptions that the curve marked Bruce angle would be raised at all points by about ten degrees, if that were the correct direction of wave arrival with respect to the ground, and consequently would proceed through the plot of Fig. 12 at a distance several times farther from the Carter curve than is indicated here by the curve marked "Bruce angle".

Q. 995. Please refer to the Bethenod French patent No. 625,293. As I understood the testimony of Mr. Kelley with respect to this patent, he stated in effect that the structure shown therein represented to one skilled in the art a V antenna, considering the image; do you agree?

A. No, I do not. I have already explained how the necessity of assuming a true image from a perfect ground is not a practical case and cannot be attained. In this instance there is another difference in that the wire from B to C, which is supposed to be the radiating part of the Bethenod antenna, is at a considerable vertical distance from ground at the point A, and consequently, even assuming that there could be an image of the radiating part in perfect ground, it would be far below the ground, as far below as the elevation from A to B, and consequently would not constitute a V.

Q. 996. What is your understanding of the teachings of this patent with respect to the use of long wires?

A. The only statement I could find which bore on that is at the top of page 2 of the translation, which says that the length BC, that is, the radiating portion to which I referred, is preferably chosen to be a whole number of half waves. That, of course, has the meaning that the suggestion is met whether the wire is one half wave length, two half wave [fol. 630] lengths or one wave length long, and so forth, by any integral number of half waves.

There is no advantage stated for making the wire longer than half a wave length, and there is a very good reason for following the half-wave requirement that is stated, namely, because the voltage loop comes at the end B and consequently at the top of the section AB, so that the open end of the radiation-cancelling wire F may have a voltage loop and operate to neutralize the radiation from the vertical AB, which is one of the objects, if not the object, of the Bethenod arrangement. That is done just as effectively with the wire length from B to C of one half wave length or of one wave length as it is with a longer wire.

Of course, the drawing indicates that the length BC is not very long, but that is a mere indication.

Q. 997. Now, Mr. Kelley, in answer to Q. 463 (R. p. 352), stated that this patent relates to a short wave directional antenna. Do you agree with that statement?

A. No, I think he must have misunderstood the last paragraph of the specification just before the résumé. There it states that several antenna arrangements of the same kind, suitably positioned or orientated in reference to one another, may be combined in one and the same station with a view of insuring directional properties. That is the only reference I found as to directional operation, and that teaches a combination of several of the simple antennas into an array to produce directive radiation.

It does not teach that the single antenna of Bethenod's type is directional.

Q. 998. Is there in this patent any mention or suggestion of the utilization of the effect of an image in the operation of its antenna?

[fol. 631] A. No, I could find no suggestion of that. In fact, I found no mention of an image.

Q. 1000. Is there any suggestion that Bethenod considered his single wire as the equivalent of two wires?

A. No, I found no suggestion of that, either.

Q. 1001. Please refer to the Abraham 1898 and 1901 articles. Did Abraham in either of those articles, suggest any practical application of his mathematical analysis of the radiation patterns of a conductor?

A. No, I found no suggestion of a practical application.

Q. 1003. Did he suggest that these analyses might be useful to obtain directive radiation?

A. Not at all.

Q. 1004. Did he consider the radiation pattern which might result from combining two or more conductors?

A. No.

Q. 1005. At the time that Abraham made these analyses was there available in the art any source of high frequency oscillations which could be used to excite a wire or conductor at a single harmonic frequency?

A. No, the only source available was the spark excitor, which set up simultaneously the fundamental vibration of the conductor and with it a number of harmonics; the fundamental vibration in general being much stronger than any of the harmonics.

Q. 1006. What do you understand that Abraham was seeking to explain in these articles?

A. He was seeking to explain the fact that a spark-excited radiating conductor could vibrate simultaneously at its fundamental frequency and at a number of harmonic or nearly harmonic frequencies. That is to say, that all of these currents of different frequencies could co-exist in such an oscil- [fol. 632] lator. Having shown that, he investigated the radiation from a wire or an assumed conductor, carrying all of those frequencies simultaneously, and he analyzed the total radiation from that wire into the part of that total radiation that might be contributed by each of the several simultaneously-excited frequencies in the conductor.

Q. 1007. Mr. Hogan, have you had charts prepared showing the situation with respect to radiation in the horizontal and vertical planes of the bisector in free space of a V antenna eight wave lengths long, with an included angle, I think, of 12 degrees?

A. Yes, I have two graphs which show the power distribution of the radiation both in a horizontal plane and in a vertical plane along the bi-sector of a pair of horizontal wires each eight wave lengths long and arranged with an included angle of 12 degrees. This corresponds approximately to the range given in the second Lindenblad patent which said a wire length of from five to ten wave lengths, and with spacing at the end of one-fifth of the wire length. So that these patterns show the theoretical free space radiation from an antenna of that character arranged as a horizontal V.

Q. 1008. How does that angle compare with the angle recommended for wires of that length in the third Carter patent?

A. It is much less, that is to say, the angles shown in these plots are much less.

To continue: The chart showing the power distribution in the horizontal plane shows a power proportional to a little over six and a half in the geometrical line of the bisector, and a substantially greater power of something over eleven [fol. 633] in the general direction of the bisector, but inclined at something like 20 degrees either side of the geometric bisector line. This is the fanwise radiation of which I spoke.

The vertical plane chart shows the concentration of the radiated power into the general plane of the wires, that is around the plane of the wires, and with the large lobes extending somewhat, both upwardly and downwardly.

Mr. Blackmar: I offer in evidence as one exhibit the two charts referred to by the witness in his immediately preceding answers.

(Marked Plaintiff's Exhibit 52 in evidence.)

Q. 1010. In describing the chart covering power distribution in the vertical plane of Plaintiff's Exhibit 52, did you state what it shows with respect to radiation along the bisector in that plane?

A. I think I said it was the vertical plane of the bisector.

Q. 1011. Please look at Defendant's Exhibit FF, which I understand purports to show radiation in the vertical plane of wires four wave lengths long with the angle of 11.4 degrees, as stated thereon. Please consider that with respect to the radiation in the direction of the axis of the system.

A. It shows that in the vertical plane for this four wave V, the radiation is concentrated around the plane of the wires, that is to say vertically, in the direction in which the wires extend. It is generally similar to the vertical plot of Exhibit 52, except as to proportions, and as to the fact that the two ends on the bisector are pointed and go out further than in the case of Exhibit 52, go out further in proportion.

[fol. 634] Q. 1013. In connection with Plaintiff's Exhibit 52, have you had prepared charts showing the comparative gain along the bisector as compared to a di-pole as a standard; that is, the comparative gain of wires eight wave lengths long with an angle between them of 12 degrees?

A. Yes, I have had such charts prepared. The first one to consider is the power distribution in a horizontal plane of a horizontal di-pole which is marked on the chart that

way. That shows by the simple figure 8 in the center of the chart, the distribution measured in the horizontal plane around the di-pole or half wave wire, which is assumed to lie in the plane of the paper and from the top to the bottom of the sheet. The radius of the lobes on each side of the wire is unity, because we are taking that amount as standard radiation, that is, the radiation in the desired direction from the horizontal di-pole.

The second chart is the power distribution in a vertical plane perpendicular to the wires of this same horizontal di-pole, and that shows a simple circle with the radius of unity. It shows the result with the di-pole as a wire extending perpendicular to the paper, and the paper being held in the perpendicular plane; therefore, the radiation is symmetrical that way and of unit value.

Now, the next sheet is the power distribution from the eight-wave-length wire, V, having an included angle of 12 degrees, plotted on a scale which uses the same power input as in the case of a di-pole, so that the extent of the radiation indicated gives a direct comparison of the relative power in the various directions shown, as between this eight-wave-length 12-degree V and the di-pole. It shows that in [fol. 635] the horizontal plane the radiation along the geometrical axis of this system, the actual gain is something over twice that of the di-pole and that in the general direction of the V antenna the radiation is about 3.7 times in power that of the di-pole.

The fourth curve is the power distribution in the vertical plane for this same V antenna, and, of course, since it is taken in the plane of the axis, the measurement—the maximum radius—of the plot coincides with that for the direction along the zero-degree line in the third chart to which I referred.

These charts represent radiation patterns in free space.

Q. 1016. Have you also had prepared charts for wires of the same length, namely, eight wave lengths, but placed at an angle in accordance with the recommendations of the third Carter patent, and plotted on the same scale as the four charts to which you have just referred?

A. Yes. I have here the vertical and horizontal power distribution for eight-wave-length wires in a V, having an included angle of 35 degrees. The power input is assumed to be the same as for the di-pole shown in the other curves to which I have just referred, and the scale of the diagrams

is the same, so that for this particular case, the power gain in any direction in either the vertical or horizontal plane of the bisector is indicated by the numerical scale.

This shows that in both the horizontal plane and in the vertical plane the principal radiation is concentrated not merely in the general direction of the bisector, but along the bisector line. Also, that the amplitude, the power [fol. 636] radiated in the direction of maximum radiation is much greater than in the case of either the di-pole or the 12-degree V antenna.

The ratio along the exact line of the bisector is given as 10 in the one chart for the vertical plane and I have just observed, as 10.2 along the bisector line for the power distribution in the horizontal plane. I think the 10.2 figure is correct for both charts, and that they should be corrected to that extent; otherwise I think they are right.

Mr. Blackmar: I offer in evidence the six charts last referred to by the witness showing comparative power distribution in horizontal and vertical planes of a di-pole and of a V-shaped antenna eight wave lengths long with an included angle of 12 degrees, and of a V antenna with wires eight wave lengths long with the angle recommended in the third Carter patent.

(Marked Plaintiff's Exhibit 53 in evidence.)

Q. 1017. What is the power gain of a pair of eight-wavelength parallel wires with the best stagger and spacing in the plane of the wires and direction of the principal lobe?

A. That I understand is 8.2 times the power that would be received from the equivalently-excited di-pole.

Q. 1018. And what is the power gain for the same pair of wires placed in V formation utilizing the angle recommended in the Carter patent, considering radiation along the bisector of the plane of the wires in free space?

A. That figures out as 10.2, and represents about a 25 per [fol. 637] cent. increase over the figure I have just given for the parallel wires.

Q. 1019. Have you had charts prepared comparing two four-wire systems, each of the wires in each case being eight wave lengths long, in one case utilizing the arrangement of the first Lindenblad patent with the best stagger and spacing, and in the other case utilizing the arrangement of the third Carter patent with the angle recommended by him for wires of that length?

A. Yes. I have here four charts which may be considered in pairs. The first shows the power distribution in a horizontal plane of four horizontal parallel wires each eight wave lengths long spaced and staggered for maximum addition and cancellation. That is shown in terms of power for these wires in free space with the angles drawn in reference to the wire direction. With that may be considered also the power distribution in the vertical plane of the beam of these same wires.

This second chart differs from those which I have already used because of its reference to parallel wires, in that it is taken in the plane of the beam and not in the plane of the axis of the wire system. The gain for this system, that is, the power measurement, is about 16.4, as shown in the curve.

The other pair of curves is plotted for a double four-wire V antenna, each of the V's being horizontal and in the same plane, the wires being eight wave lengths long, as in the case of the parallel horizontal wires, but being set up with the 35-degree angle recommended for that wave length and wire length in the second Carter patent. The V's are spaced [fol. 638] and phased in quadrature. In other words, this corresponds generally to defendant's antenna No. 8 which we have discussed and of which the model, Exhibit 29, was a representation. This shows, in the horizontal plane, the narrow main beam giving a power gain of something over 20,—20.4, I think,—and in the vertical plane a somewhat wider lobe of radiation, but nevertheless principal radiation occurring in one direction and having, of course, the same amplitude of 20.4. That value of 20.4 may be compared with the value of about 16 which was had when the four parallel wires were used. The difference is due to the fact that when best cancellation and addition of the main radiation is had with the four parallel wires, the relation in the rest of space where the extraneous lobes exist is not as favorable for producing the directivity one desires as when one uses a V of the Carter patent and cancels the opposite lobes on the two sides of the wire, and of course, a larger part of the stray radiation in the other directions. That better effect of the case of the V is reflected in the increased gain along the bisector of the beam line.

One of these is marked "Wires in free space", and the other should have been so marked, because they all refer to that.

Mr. Blackmar: I offer the four charts referred to by the witness in respect to power distribution of four-wire antennas in evidence.

(Marked Plaintiff's Exhibit 54 in evidence.)

Q. 1020. In the course of the testimony on behalf of the defendant, it was stated, as I understand it, that the de- [fol. 639] fendant, by utilizing a smaller angle than the angle recommended in the Carter patent, derived some gain in actual direction of propagation of the waves. I hand you Plaintiff's Exhibits 37, 38, 39 and 40 for identification, and I ask you to explain what they show in that respect; this is with respect to antenna No. 2 rebuilt, as I understand it.

A. These curves correspond to the four plots that the defendant introduced with respect to antenna No. 8, and I think antenna No. 2, originally, but these correspond to antenna No. 2 as it was rebuilt. They show a power distribution in the vertical plane for the 8.14-wave-length wires having included angles in one case of 40 degrees, as used, and larger than recommended by Carter, and in the other case of 34.66 degrees, which is the angle given in the Carter patent as preferred. The results are plotted for each angle, both in free space and over perfect ground.

The graphs show that with the preferred angle the radiation in free space would be about 9.6 in power for the preferred Carter angle, and about 8 for the 40-degree angle actually used.

They also show that over perfect ground, where the addition of energy reflected upward from the ground beyond the antenna comes into play, the power distribution would be 18.3 in the direction approximately 9 degrees upward from the ground with the angle of 40 degrees between the wires as actually used, but would be increased from 18.3 to about 23.2 if the angle of 40 degrees actually used had been reduced to a smaller angle of 34.66 degrees, as recommended in the Carter patent as the preferred value for the V.

[fol. 640] Mr. Blackmar: I offer in evidence these exhibits, namely Plaintiff's Exhibits 37, 38, 39 and 40 for identification.

(Marked Plaintiff's Exhibits 37, 38, 39 and 40 in evidence.)

Q. 1021. Please refer to Defendant's Exhibits Y and Z. Do these diagrams indicate in your opinion anything as to

comparative directivity when a V antenna is composed of wires of seven and three-quarter wave lengths long as compared to a V antenna having wires eight wave lengths long, each utilizing the angle recommended in the third Carter patent for wires of those lengths?

A. These are radiation plots intended to show part of the pattern around a single wire. In the one case, seven and three-quarter wave lengths long, and in the other case eight wave lengths long. They do not show the radiation of a V made of either one of those wires as its side element, but so far as one can judge from the graph here, the directivity of the two V's would seem to be about the same. There is no striking difference either as to angle or extent of the lobes in the two cases, although the length of the eight wave length lobe is slightly over 30, whereas that for the 7¾ is slightly under 30. Unless the entire pattern for the V's were computed in the two cases, and even then until it had been checked by measurements, one could not give a positive answer, but I can say that the indications are there would be no great difference between the two.

Cross-examination.

By Mr. Darby:

X Q. 1173. Mr. Hogan, I call your attention to the third and fourth sheets of Plaintiff's Exhibit 54, which show [fol. 641] the power distribution in vertical plane of the beam, four horizontal parallel wires, each eight wave lengths long spaced and staggered for maximum addition and cancellation of wires in free space. Was the spacing assumed in making these charts determined in the manner taught by Fig. 4 of the first Lindenblad patent?

A. I understand that it was determined as to the stagger angle in accordance with Fig. 4, but not as to the spacing between the wires.

X Q. 1174. Now I understand that a half wave di-pole will give a beam of radiation, a principal beam of radiation along some particular direction. If I placed a second half wave di-pole fed in phase there would be a beam of principal radiation from those two that would be about twice the power of the single di-pole, is that right?

A. Well, of course, not a beam for a di-pole but a doughnut pattern, but the last part of your question would be right, it would be broadside when they are fed in phase.

X Q. 1175. And there would be a power gain of about two to one?

A. Something like that.

X Q. 1176. If I place a wire eight wave lengths long to use as an antenna, that is equivalent to sixteen half wave di-poles placed end to end, is that right?

A. Well, there are sixteen half wave sections on the wire, but they are fed alternately as to phase in the long wire.

X Q. 1177. And if I made that into a V, then there would be sixteen in each wire or a total of thirty-two?

A. So far as the total number of half wave sections is concerned, and without regard to their relative phases.

X Q. 1178. Referring to Plaintiff's Exhibit 53, I understand that the first sheet, power distribution in horizontal plane of horizontal di-pole, that is for a half wave di-pole, [fol. 642] is it not?

A. That is right.

X Q. 1179. And the third sheet, which is labeled "Power distribution in horizontal plane, horizontal wires eight wave lengths long, included angle 12 degrees, power input same as for di-pole," the power angle in this last instance in the direction indicated by the zero line is approximately twice that indicated along the same zero line as illustrated in the first sheet of power distribution in horizontal plane of horizontal di-pole, is that correct?

A. Yes, about 2.2.

X Q. 1180. And I gather from one of your previous answers this morning that you would obtain about that same degree of power gain if you used two half wave di-poles?

A. In that particular direction.

X Q. 1181. In that particular direction?

A. But you would have a totally different radiation pattern.

X Q. 1182. In that particular direction you would have approximately the same gain?

A. That is about right.

Redirect examination.

By Mr. Blackmar:

R. D. Q. 1230. There was reference this morning to a wire, an antenna wire eight wave lengths long, and there was, as I understood it, a suggestion that it might have some equivalence or some relationship to 16 di-poles. With an antenna utilizing a system, for example, of 16 di-poles,

what would the feeding arrangement of such an antenna be or have to be?

A. A typical arrangement of that sort would have 16 di-poles independently supported, perhaps horizontally, spaced with regard to each other, and each fed at the [fol. 643] center with a transmission line connection. In other words, there would be a multiplicity of divided transmission lines feeding each of the 16 di-poles.

R. D. Q. 1231. How does that compare as to simplicity with building two wires, each eight wave lengths long?

A. The di-pole case is obviously much more complicated.

R. D. Q. 1232. Have there been types of antennas referred to in this case, which are instances of multiple di-pole arrangements?

A. Yes.

R. D. Q. 1233. What are they?

A. Those used at the Sayville Station, which were described by Mr. Hansell were the only practical cases I recall. There may have been some reference in the publications to them.

R. D. Q. 1234. Are there other types of antennas which utilize half wave radiators, possibly not referred to as di-poles?

A. Oh, yes, there are the curtain types of antennas, for example, the model A antenna, and the Marconi beam, in which the effect is generally that of a series or multiplicity of di-poles.

Mr. Darby: That is all.

Mr. Brown: I offer in evidence a certified copy of Bruce's application, Serial No. 513,063 for improvement of horizontal V antenna, which is the application filed in the United States, and upon which the British patent was filed under the convention.

Mr. Darby: If your Honor pleases, I make the same objection to this as to the others, as to its relevancy and materiality.

(Marked Plaintiff's Exhibit No. 55 in evidence.)

[fol. 644] Mr. Blackmar: In the course of the progress through the Patent Office of the application which resulted in the first Lindenblad patent in suit, two British patents were cited, namely, British patent No. 233, 346 and British patent No. 251,638. I offer those two patents in evidence.

(Marked Plaintiff's Exhibits Nos. 57 and 58, respectively, in evidence.)

[fol. 645] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

STIPULATION AS TO NARRATIVE FORM OF EVIDENCE

It is Hereby Stipulated and Agreed, by and between the Solicitors for the respective parties to the above entitled suit, subject to the approval of this Court, that the annexed statement of evidence is true, complete, and properly prepared and may be treated and considered as a record of the proceedings at the trial of said cause in making up the transcript of record on the appeal by the plaintiff; and that the testimony in this stipulated statement of evidence (except the experts' testimony) is stated in narrative form except where it was desired to retain the exact words of the witness; and it is

Further Stipulated and Agreed that either party may refer to the original transcript of testimony taken at the trial for correction of errors in the printed record.

Dated, New York, N. Y., October 6th, 1937.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

[fol. 646] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ORDER APPROVING NARRATIVE STATEMENT OF EVIDENCE

Now, on this 8th day of October, 1937, on reading and considering the annexed stipulation of the Solicitors for the respective parties, it is hereby

Ordered that the annexed narrative statement of evidence in the form provided by said stipulation be and it hereby is approved as true, complete and properly prepared; and it is

Further Ordered that the same be filed as a statement of the evidence to be included in the record on appeal.

Marcus B. Campbell, U. S. D. J.

Vol. II

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
PETITIONER,

vs.

RADIO CORPORATION OF AMERICA

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT

PETITION FOR CERTIORARI FILED JUNE 17, 1938.

CERTIORARI GRANTED OCTOBER 10, 1938.

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57—Levy British Patent No. 233,346	925	729
58—Levy British Patent No. 251,638	935	738
Defendants Exhibits:		
"A"—Sketches from file wrapper of Lindenblad patent No. 1,927,522	939	742
"F"—Chart of obtuse-angled V antenna	941	743
"G"—Chart of radiation patterns of wires 4 wave lengths long at an angle of 122°	943	744
"S"—Chart of radiation patterns of defendant's antenna No. 8 and of a V antenna with included angle of 50°	944	745
"T"—Chart of radiation patterns of defendant's antenna No. 2 and of a V antenna with included angle of 35.6°	945	746
"U"—Carter patent No. 2,027,020	946	748
"V"—Folder of publications (only translations reproduced)	960	761
Abraham 1898 article	960	761
Abraham 1901 article	970	770
Bergman article	986	785
Bontsch-Bruewitsch article	992	790
"W"—Enlargement of Fig. 12 of Carter Patent No. 1,974,387, with notations	1022	820
"X"—Chart of radiation resistance	1024	821
"Y"—Chart of radiation pattern of a wire 8 wave lengths long	1025	822
"Z"—Chart of radiation pattern of a wire 7¾ wave lengths long	1026	823
"AA"—Folder of patents (only translations of foreign patents reproduced)	1027	824
Bethenod French patent No. 596,787 and drawing	1027	824
Bethenod French patent No. 625,293 and drawing	1061	828
Braun U. S. patent No. 768,345	1065	831
Reuthe U. S. patent No. 1,314,095	1039	836
Brown British patent No. 14,449 of 1899	1043	839
Heising U. S. patent No. 1,562,961	1049	846
Levy French patent No. 593,570 and drawing	1065	861
Levy French patent of addition No. 30,798 and drawing	1071	867
Melton "Q. S. T." Article	1079	874
Pages 156 and 157 of Mills' Book	1083	878
Takagishi Japanese Patent No. 70,583 and drawings	1087	881

	Original	Print
Record from D. C. U. S., Eastern District of New York—Continued.		
Order approving narrative statement of evidence—Continued.		
Defendants Exhibits—Continued:		
"BB"—Chart of radiation patterns of wires 16 wave lengths long at an angle of 40.8°	1103	896
"CC"—Chart of radiation pattern of V antenna 4 wave lengths long with included angle of 11.42°	1104	897
"DD"—Chart of radiation pattern of V antenna 8 wave lengths long with included angle of 11.4°	1105	898
"FF"—Chart of radiation pattern of V antenna 4 wave lengths long with included angle of 11.4°	1106	899
"GG"—Chart of radiation pattern of V antenna 8 wave lengths long with included angle of 11.42°	1107	900
"HH"—Charts of radiation pattern showing effect of worst possible ground	1108	901
"JJ"—Diagram dated September 28, 1928, from Bruce note book	1110	902
"KK"—Sheet with formula from Levin and Young I. R. E. article	1111	903
"LL"—Diagram dated July 26, 1928, from Bruce note book	1112	904
"MM"—Pages of Bruce note book	1114	905
Entry dated May 13, 1926	1114	905
Entries dated May 14, 1926	1115	906
Entry dated July 19-21, 1927	1117	908
Entry dated August 2, 1927	1118	909
Entry dated August 9, 1927	1119	910
Entry dated August 10, 1928	1120	911
Entry dated March 5, 1930	1121	912
Letter dated July 25, 1927, from Couzens to Bruce	1122	913
"NN"—Bruce August, 1931, I. R. E. Article	1124	914
"OO"—Levin and Young, October, 1926, I. R. E. article (only pages 675 and 681 reproduced)	1152	942
"PP"—Englund record dated May 14, 1926	1154	944
"QQ"—Beck note book pages	1156	945
"UU"—File wrapper of Lindenblad Patent No. 1,927,522	1172	960
"VV"—File wrapper of Carter Patent No. 1,974,387	1240	1028
Opinion, Campbell, J.	1344	1133
Stipulation re findings of fact and conclusions of law	1381	1158
Final decree	1382	1158
Petition for appeal	1384	1159
Order allowing appeal	1385	1159

	Original	Print
Record from D. C. U. S., Eastern District of New York—Continued.		
Assignment of errors	1385	1160
Undertaking for costs.....(omitted in printing)..	1389	
Citation .....(omitted in printing)..	1391	
Statement re stipulations and orders extending time to file record, etc.	1392	1162
Stipulation extending time to file record to November 26, 1937, and order thereon	1393	1162
Praecipe for record and order thereon	1394	1163
Stipulations extending time to file record and orders thereon	1397-a	1165
Stipulation as to the correctness of record and order thereon	1398	1166
Clerk's certificate .....(omitted in printing)..	1399	
Proceedings in the U. S. C. C. A., Second Circuit	1400	1167
Opinion, Manton, J.	1400	1167
Judgment	1412	1175
Clerk's certificate	1414	1176
Order allowing certiorari	1415	1176

[fols. 647-650] PLAINTIFF'S EXHIBIT No. 1

462

April 12, 1927. P. S. CARTER 1,623,996

RADIO TRANSMISSION SYSTEM

Original Filed June 25, 1923

Fig. 1

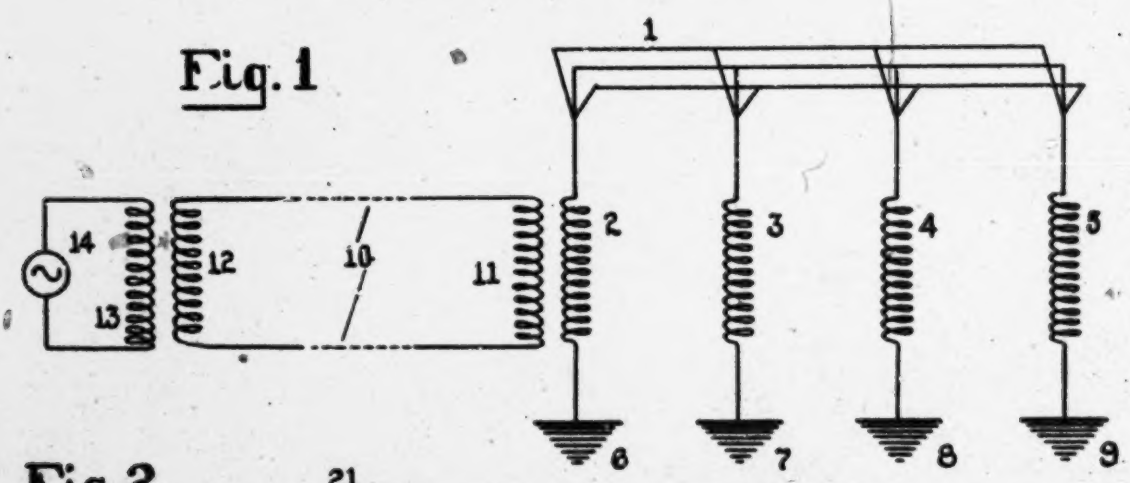


Fig. 2

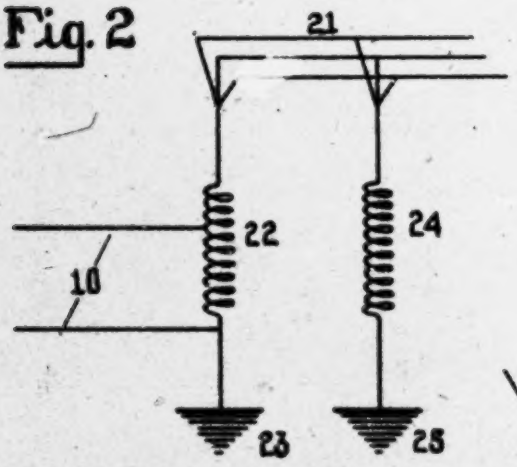


Fig. 5

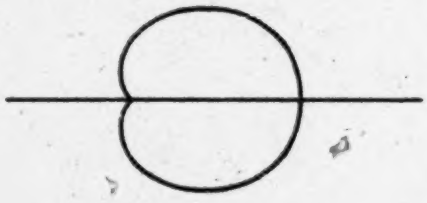


Fig. 3

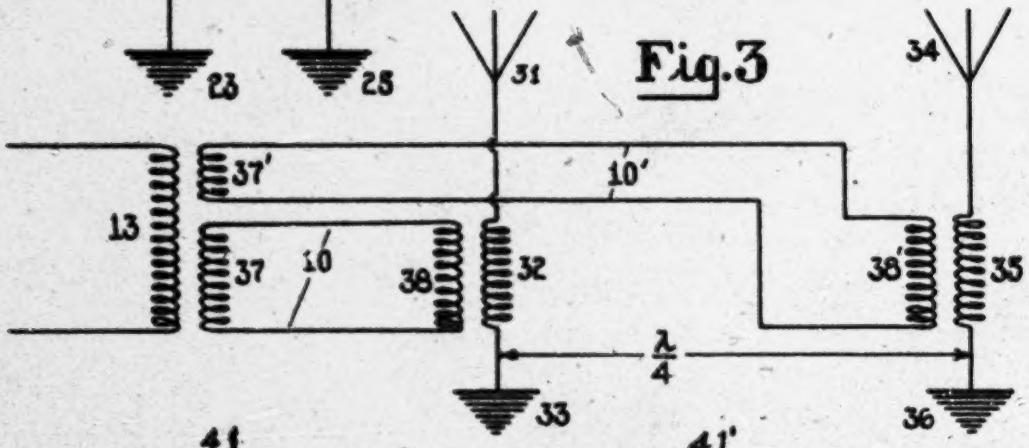
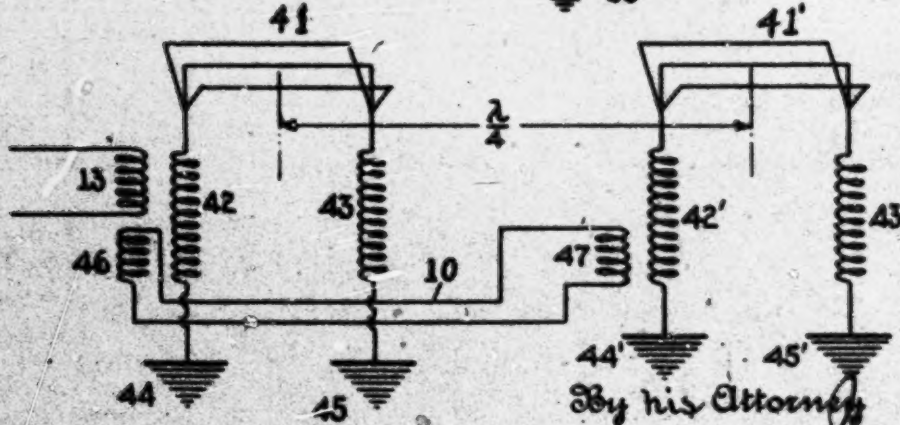


Fig. 4



Inventor

PHILIP S. CARTER

By his Attorney

Ira J Adams

1,623,996

Patented Apr. 12, 1927.

UNITED STATES PATENT OFFICE.

PHILIP S. CARTER, OF NEW BRUNSWICK, NEW JERSEY, ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE.

RADIO TRANSMISSION SYSTEM.

Application filed June 25, 1923, Serial No. 647,463. Renewed February 12, 1925.

This invention relates to a new and improved radio signaling system and more specifically to improved means for transferring radio frequency energy, generated at a power house, to the antenna or energy radiating circuit.

In the past it has been the custom to erect the antenna of a transmitting system as close as possible to the point where the radio frequency power is generated in order to have a minimum power loss between the generator and the antenna, in the interests of efficiency and economy. However, circumstances occasionally arise where local geographical conditions or considerations of economy render it desirable to make use of an antenna which is located at a distance from the power house. In the past, under such conditions, it was not possible to work efficiently, particularly with short waves, since a given length of transmission line with such waves represents a greater electrical distance than with long waves.

My invention has for objects the provision of a transmission line which will supply radio frequency energy from a power house to an antenna located at a considerable distance away, thus making possible the utilization of existing apparatus at a high efficiency where hitherto only a low efficiency was possible. Another object of the invention is to provide a new and improved system giving directional transmission utilizing separate antennæ fed from a single source through a plurality of transmission lines.

My invention is illustrated in the accompanying drawing, in which—

Figure 1 represents a multiple tuned antenna connected to a source of power through a transmission line of relatively great electrical length.

Figure 2 shows an equivalent method of coupling the transmission line to the antenna.

Figures 3 and 4 represent different forms of a directional system according to my invention, utilizing a plurality of antennæ supplied from a single source by means of transmission lines.

Figure 5 shows the directional characteristics of the arrangement disclosed in Figures 3 and 4.

My invention, both as to its theoretical principles and its practical application, will best be understood by reference to the specification in connection with the drawing, but its scope will particularly be pointed out in the appended claims.

Referring to Figure 1, 1 designates a long or multiple tuned antenna grounded at points 6, 7, 8 and 9 through inductances 2, 3, 4 and 5. A transmission line 10 is coupled by means of coil 11 to inductance 2 as will be more particularly pointed out later. An inductance 12 connected across said transmission line is coupled to inductance 13 connected across the terminals of a source of power 14. For the purpose of example this is shown in the drawing as an alternator, although any other suitable source, such for instance as an arc converter or a vacuum tube oscillator may be used for supplying power to the transmission line and antenna.

In order to economize in the generating and power transmitting apparatus, it is highly desirable that the apparatus should work at unity-power factor; that is to say, that the current and voltage in the transmission line should be in phase. The power loss (including radiation) in any transmission line is I^2R where I represents current and R the effective A. C. resistance, including radiation resistance. When the transmission is at unity power factor, losses in the line are a minimum. Such a result may be obtained if the transmission line is made reflectionless or of electrically infinite length. Under these conditions no waves can be reflected back from the ends to interfere with the natural flow of energy into and out of the transmission line. This result may be obtained by closing the transmission line 10 at 11 in such a manner that the effective impedance at the load end of the line is equal to the surge impedance of the transmission line.

I have found that in the case of a multiple tuned antenna this condition is obtained when the feed ratio is equal to $\sqrt{\frac{Z_o}{R}}$ where Z_o is equal to the surge impedance of the transmission line $\left(=\sqrt{\frac{L}{C}} \text{ approx}\right)$ and "R" equals the antenna resistance, or stated differently, the antenna resistance multiplied by the square of the feed ratio should be equal to the surge impedance of the line.

Referring to Figure 2, an equivalent

method of connecting the transmission line 10 to a multiple tuned antenna is shown. Here, 21 designates the antenna grounded at 23, 25, etc. through coils 22, 24, etc. The transmission line 10 is closed through a suitable amount of coil 22 such that the effective impedance of this part of coil 22 with its antenna load is equal to the surge impedance of the line.

Referring to Figure 3, I have shown a plurality of open antennæ 31 and 34 provided with inductances 32 and 35 and grounded at 33 and 36. These antennæ are located ¼ wave length apart and are energized by means of transmission lines 10 and 10′ which are coupled through coupling coils 37, 37′ and 13 to a generator (not shown) and through coils 38 and 38′ to coils 32 and 35. Obviously, the same adjustment of coupling coils 38 and 38′ is made as before.

Figure 4 shows an arrangement substantially equivalent to that shown in Figure 3 with the exception that two multiple tuned antennæ are used instead of the two open antennæ. In this figure 41 and 41′ represent two multiple tuned antennæ grounded at 44, 45 and 44′, 45′, respectively through inductances 42, 43 and 42′, 43′. A generator (not shown) is arranged to feed antenna 41 and energy is supplied to antenna 41′ by means of the transmission line 10 coupled to the source by means of coils 12 and 46 and to antenna coil 42′ by coil 47. The coupling between the transmission line and the antenna should be adjusted to give an effective impedance equal to the surge impedance of the line. It will be seen that this arrangement is somewhat directional as shown in Fig. 5.

It is to be noted that my transmission line lends itself particularly to directional systems comprising a plurality of antennæ, since the proper phase relation of currents in the various antennæ can readily be obtained with a maximum efficiency of transmission line.

While I have shown and described the preferred form of my invention I wish it understood that I do not limit myself to the arrangements shown and described, but that modifications and changes may be made within the scope of my invention as will be evident to those skilled in the art to which it appertains.

Having described my invention, what I claim is:

1. In a radio signalling system, the combination of an energy radiating circuit, a source of power for energizing said circuit and a transmission line of electrically infinite length connecting said circuit and said source.

2. In a radio signalling system, the combination of an energy radiating circuit, a source for supplying energy to said circuit and a transmission line connecting said source and said circuit, said transmission line being constructed and arranged so as to be substantially reflectionless.

3. In a radio signalling system, the combination of an antenna constructed and arranged to radiate energy, a source for supplying energy to said antenna and a conducting line connecting said source and said antenna, said line being so constructed and arranged as to prevent the formation of standing waves thereon.

4. In a radio signalling system, the combination of an antenna arranged to radiate energy, a source for supplying said antenna with energy to be radiated and means for transferring energy from said source to said antenna, said means being so constructed and arranged that the voltage and current components of the energy travelling thereon are always in phase.

5. In a radio signalling system, the combination of an antenna arranged to radiate energy, a source for supplying energy thereto and a transmission line connecting said source and said antenna, the effective impedance at the antenna end of said transmission line being equal to the surge impedance of the line.

6. In a radio signalling system, the combination of a multiple tuned antenna, a source of power for said antenna and a transmission line for connecting said antenna and said source, characterized by the fact that the antenna resistance multiplied by the feed ratio squared is substantially equal to the surge impedance of the line.

7. In a radio signalling system, the combination of a plurality of antennæ, a single source for supplying energy to all of said antennæ and transmission lines of electrically infinite length for supplying energy from said source to said antennæ.

8. In combination, antennæ having a single source of power supply and grounded through inductances, the source of supply energizing that part of the inductance necessary to give an effective load resistance equal to the surge resistance of transmission means connecting the source and the antennæ.

PHILIP S. CARTER.

[fols. 651-654] PLAINTIFF'S EXHIBIT No. 2

465

May 16, 1933. P. S. CARTER 1,909,610

ELECTRIC CIRCUIT

Filed March 12, 1930

Fig. 1

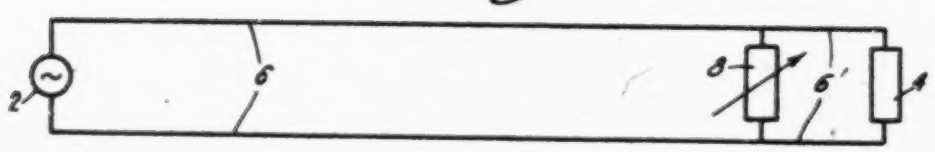


Fig. 2

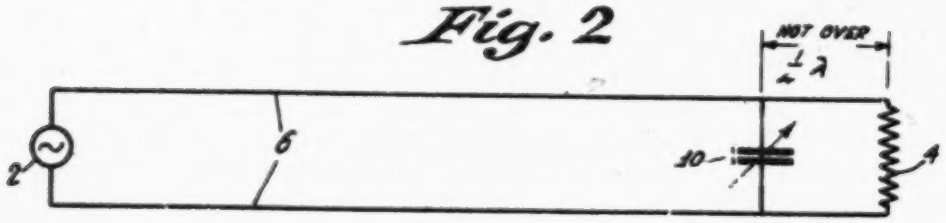


Fig. 3

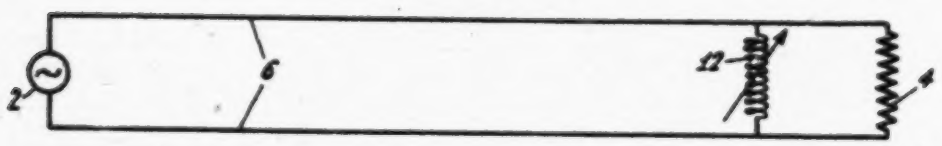


Fig. 4

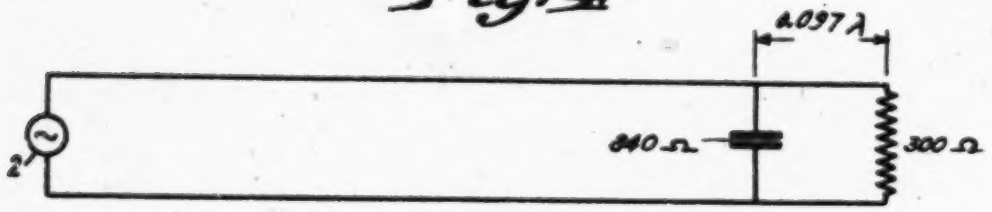
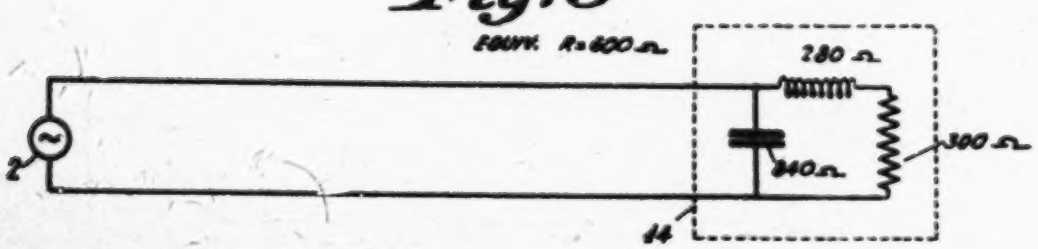


Fig. 5



INVENTOR
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BY W. S. Grover
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Patented May 16, 1933

1,909,610

UNITED STATES PATENT OFFICE

PHILIP STAATS CARTER, OF PORT JEFFERSON, NEW YORK, ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE

ELECTRIC CIRCUIT

Application filed March 12, 1930. Serial No. 435,381.

This invention relates to electric circuits and especially to a transmission line supplying high frequency currents to a high frequency load circuit. In order that the line transmit energy at best efficiency; that is to say, without reflection, it is desirable that the line be terminated by a load which equals in impedance the surge impedance of the line. As lines and loads are independently designed; or, as it often occurs that existing lines must be connected with existing loads which do not have the requisite values of impedance for best energy transmission over the lines, it is an object of my invention to provide a method and means for terminating a line to which a load is connected so that the termination means combined with the load presents the correct impedance to the line. More specifically, I accomplish this by connecting a variable reactance across the line at a distance away from the load such that the circuit formed thereby including the variable reactance, the line portion between it and the load, and the load, presents an impedance equivalent to the surge impedance of the line.

In a case wherein the surge impedance is greater than the load impedance or resistance, I have discovered that by connecting a capacitive reactance across the line at a distance not more than one-quarter of a wave length of the energy transmitted by the line away from the load; or, by connecting an inductive reactance across the line at a distance more than one-quarter wave length but less than one-half wave length of the load, the combination of the reactance, load and portion of the line included between the reactance and the load becomes equivalent, with proper quantitative values of the electrical elements involved to the surge impedance of the line, therby facilitating efficient energy transmission.

Similarly I have discovered that when the surge impedance of the line is less than the load impedance, by connecting an inductive reactance across the line not more than one-quarter wave length away from it; or, a capacitive reactance across the line more than one-quarter wave length but less than one-half wave length away from the load, that the combination of reactance, load and portion of the line included between the reactance and the load becomes equivalent, with proper quantitative values of the electrical elements involved to the surge impedance of the line thereby properly terminating it for maximum energy transmission. Similar results can, of course, be obtained if multiples of the distances given are chosen. Thus, for example, where the surge impedance is greater than the load resistance, a capacity reactance may be connected across the line at a distance away from the load not over three-quarters and more than one-half wave length away from the load and the reactance plus the portion of the line included between it and the load together with the load will provide for the line an impedance equivalent to its surge impedance.

Although I have defined my invention in particularity in the appended claims, it may best be understood by referring to the accompanying drawing in which

Figure 1 generically discloses my invention for properly terminating the line so that the load plus the terminating circuit equals the surge impedance of the line,

Figure 2 illustrates a terminating arrangement wherein the load resistance is less than the surge impedance; or, in other words where the surge impedance is greater than the load impedance,

Figure 3 illustrates an arrangement for properly terminating a line wherein the load resistance is greater than the surge impedance of the line,

Figure 4 illustrates the actual constants used to properly terminate a line of 600 ohms surge impedance when the load thereacross is 300 ohms, and

Figure 5 illustrates the equivalent lumped electrical circuit of Figure 4.

Turning to Figure 1, a source of alternating energy 2 feeds energy to a load impedance 4 through the intermediary of the transmission line 6. In order that energy may be conveyed at maximum efficiency

along the line 6, the surge impedance of line 6 should be equal in value to the impedance of load 4. In practice, as already indicated, it rarely occurs that the load has the correct impedance value so as to match the surge impedance of the line to which it is connected. In order to properly match the load and line, according to my invention, I connect across the line at suitable distance away from the load a variable reactance 8 of such a value and at such a distance away from the load 4 that the reactance 8, the load 4 and the portion 6' of the line 6 included therebetween, equals in value the surge impedance of the line, thereby allowing of most efficient energy transfer from source 2 along the line 6.

In the case where the surge impedance is greater than the load impedance or load resistance, by connecting a capacitive reactance 10 such as shown in Figure 2 across the transmission line 6 at a distance away from the load not more than one-quarter wave length of the energy derived from source 2 and transmitted along line 6, the combination of the capacitive reactance 10 and the portion of the line 6 between it and the load resistance 4 will so terminate the line that it faces an impedance equivalent to its surge impedance. The same result is obtained by connecting an inductive reactance across the line at a distance away from the load 4 not over one-half wave length and not less than one-quarter wave length. Again, the same result, where the surge impedance of the line is greater than the load resistance, is obtained by connecting a capacitive reactance across the line at a distance away from the load between three-quarter and one-half wave length; etc. I prefer, however, to use as small a section of the line as possible in order to properly terminate it.

In the event that the surge impedance is less than the load resistance, proper line termination is obtained by connecting an inductive reactance 12, as shown in Figure 3, at a distance away from the load resistance not over one-quarter wave length of the energy transmitted by the two wire transmission line 6. The same result is obtained by connecting in Figure 3, in place of inductance 12 a variable capacitive reactance (it is to be understood, of course, that all of the reactances so far mentioned may be variable as indicated on the drawing) between one-half wave length and one-quarter wave length away from the load 4. Similarly, the same result can be obtained by connecting an inductive reactance across the line between three-quarter and one-half wave length away from the load resistance 4; etc. However, as I have stated with reference to the invention as disclosed in Figure 2, I prefer to connect a suitable reactance across the line as closely as possible to the load so as to include a minimum section of the line between the reactance and the load.

In Figure 4, I have shown the actual values of the elements involved where a line having a surge impedance of 600 ohms supplies a load of 300 ohms. In order to properly terminate a line a capacitive reactance of 840 ohms with respect to the frequency of the radio frequency energy being conducted parallels the load at a distance of 0.097 of the wave length employed.

In Figure 5 the equivalent electrical circuit 14 is disclosed and it is shown that the portion of the line included between the capacitive reactance and the load is equivalent to a lumped inductive reactance of 280 ohms.

In order to fix more clearly in mind the line sections and reactances to be used for properly terminating a line so that it faces an impedance equivalent to its surge impedance, the following table, which is self explanatory, wherein Z_0 indicates the surge impedance of the line, is given.

Load resistance.	Line section length.	Reactance necessary to match line.
Less than Z_0	Less than ¼ W. L.	Capacity.
Greater than Z_0	Less than ¼ W. L.	Inductance.
Less than Z_0	Greater than ¼ but less than ½ W. L.	Inductance.
Greater than Z_0	Greater than ¼ but less than ½ W. L.	Capacity.

What I claim is:

1. In combination, a source of energy, a load, a transmission line extending between said source of energy and said load, means for matching said load to the surge impedance of said line consisting of a reactance connected across said line between said load and said source and so arranged that a portion of said line is located between said reactance and load, said reactance having such value that the combination only of the load, portion of the line, and the reactance becomes equivalent to the surge impedance of said transmission line.

2. A combination as defined in claim 1 characterized in this, that said reactance comprises a variable element, and said transmission line comprises an unbroken, linear connection characterized by the absence of serially connected impedances between said source and said load.

3. In combination, a source of energy, a load having a predetermined resistance, a transmission line extending between said source of energy and said load and having a surge impedance greater than the load resistance, a capacitive reactance connected across said line between said load and said source and so arranged that a portion of said line not exceeding a quarter wave length is located between said reactance and said load

for matching said load to the surge impedance of said line, said capacitive reactance having such value that the combination only of the load, portion of the line, and the reactance becomes equivalent to the impedance of said transmission line.

4. In combination, a source of energy, a load having a predetermined resistance, a transmission line extending between said source of energy and said load and having a surge impedance greater than the load resistance, an inductive reactance connected across said line between said load and said source and so arranged that a portion of said line between one quarter and one half wave length is located between said reactance and load, said inductive reactance having such value that the combination only of the load, portion of the line, and the reactance becomes equivalent to the surge impedance of said transmission line.

5. In combination, a source of energy, a load having a predetermined resistance, a transmission line extending between said source of energy and said load and having a surge impedance less than the load resistance, an inductive reactance connected across said line between said load and said source and so arranged that a portion of said line less than one quarter wave length is located between said reactance and said load for matching said load resistance to the surge impedance of said line, said inductive reactance having such value that the combination only of the load, portion of the line, and the reactance becomes equivalent to the surge impedance of said transmission line.

PHILIP STAATS CARTER.

[fols. 655-670] PLAINTIFF'S EXHIBIT No. 3

470

Oct. 25, 1932. N. E. LINDENBLAD 1,884,006

ANTENNA

Filed Sept. 7, 1928 4 Sheets-Sheet 1

Fig. 1

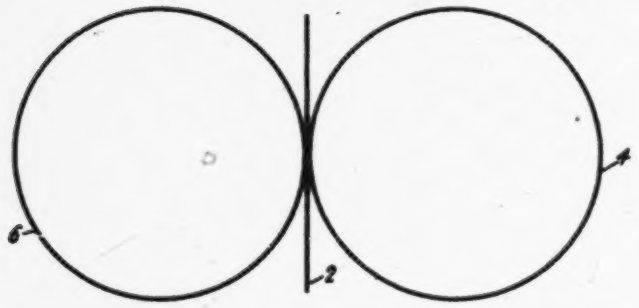


Fig. 2

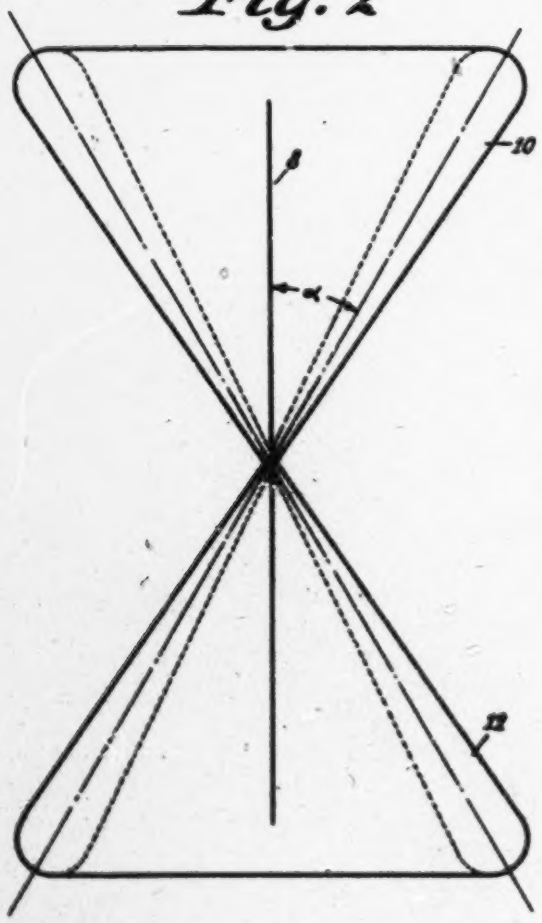
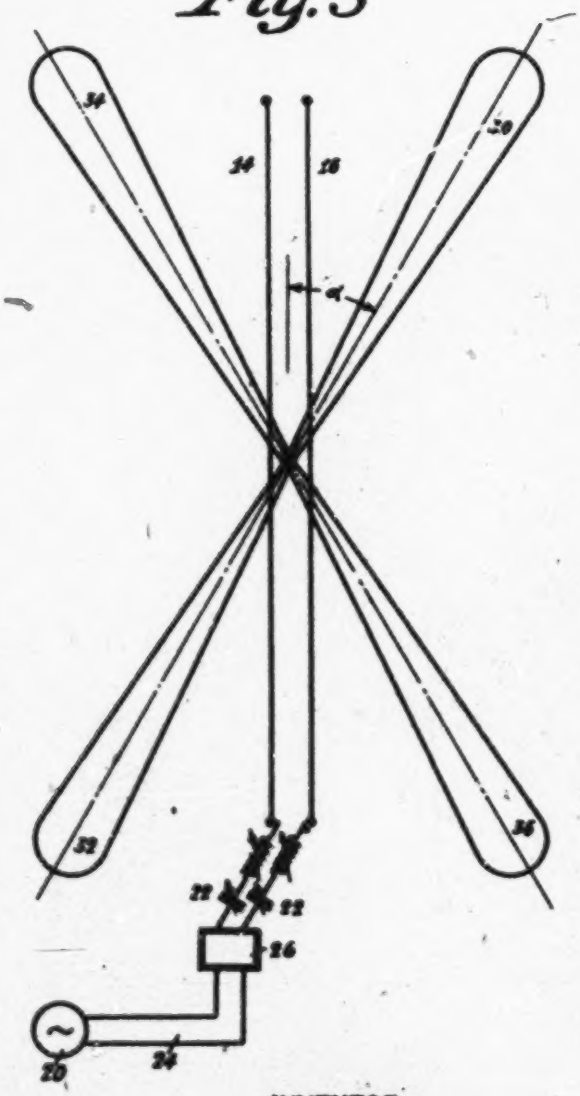


Fig. 3



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470

472

Oct. 25, 1932. N. E. LINDENBLAD 1,884,006

ANTENNA

Filed Sept. 7, 1928 4 Sheets-Sheet 2

Fig. 4

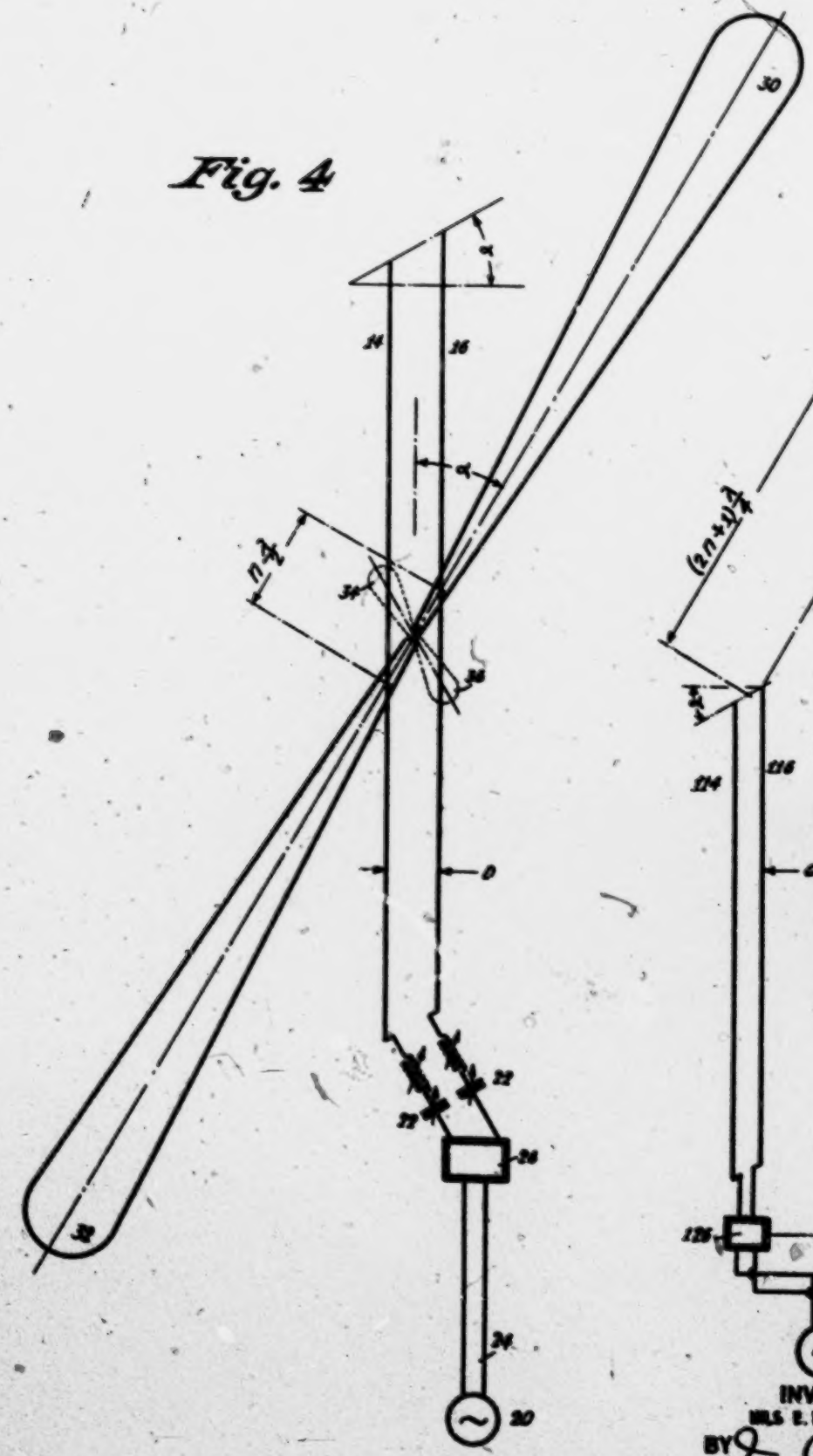
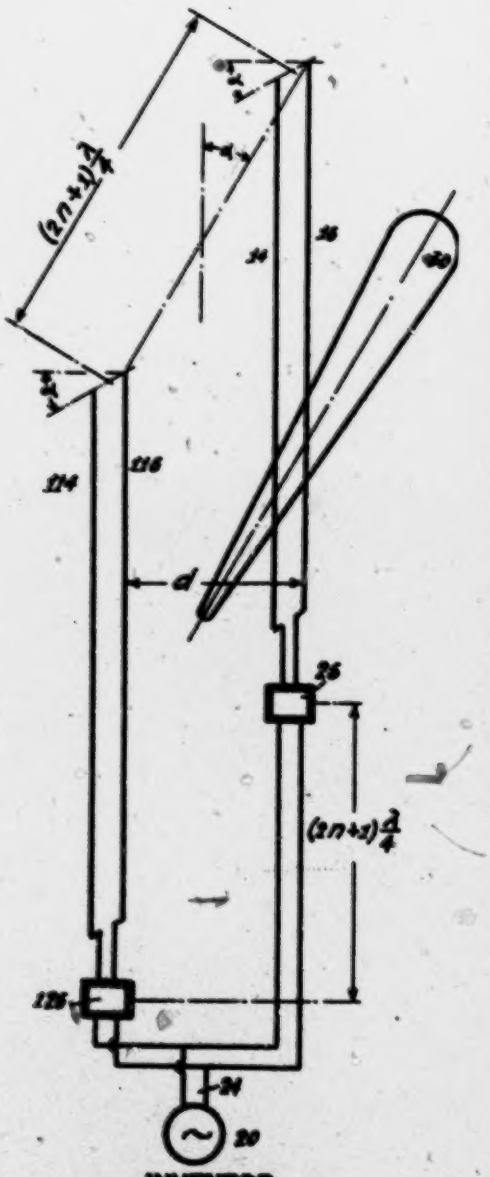


Fig. 5



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Fig. 6

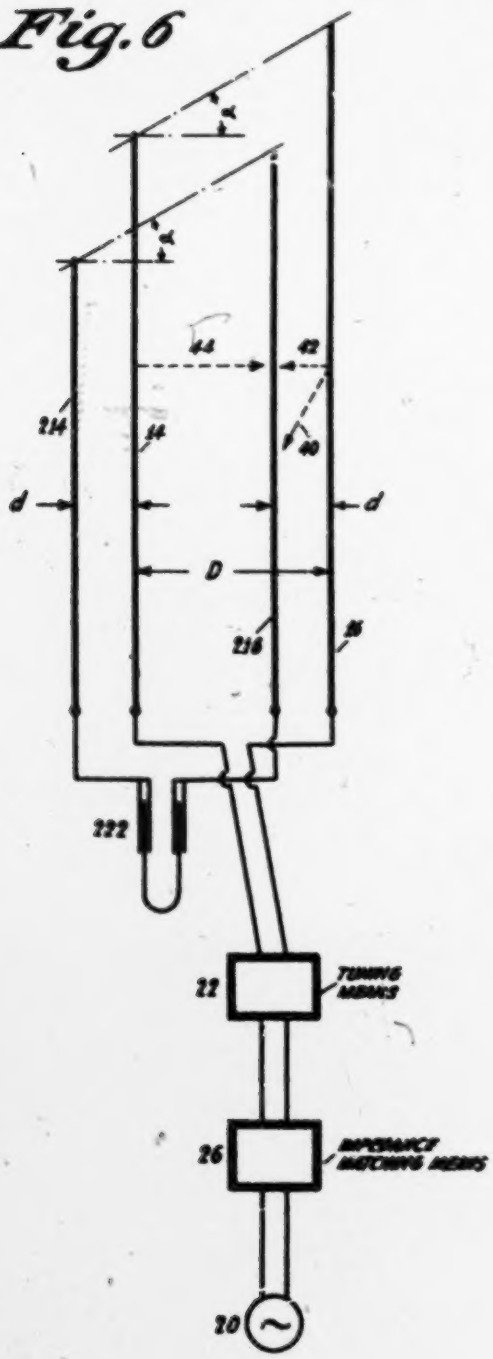
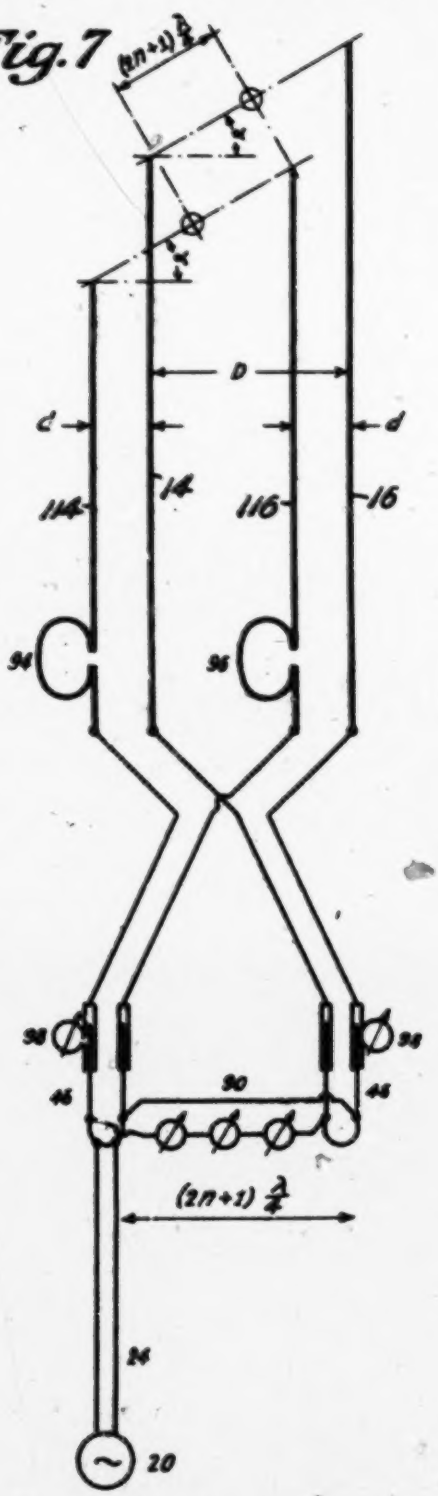


Fig. 7



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Fig. 8

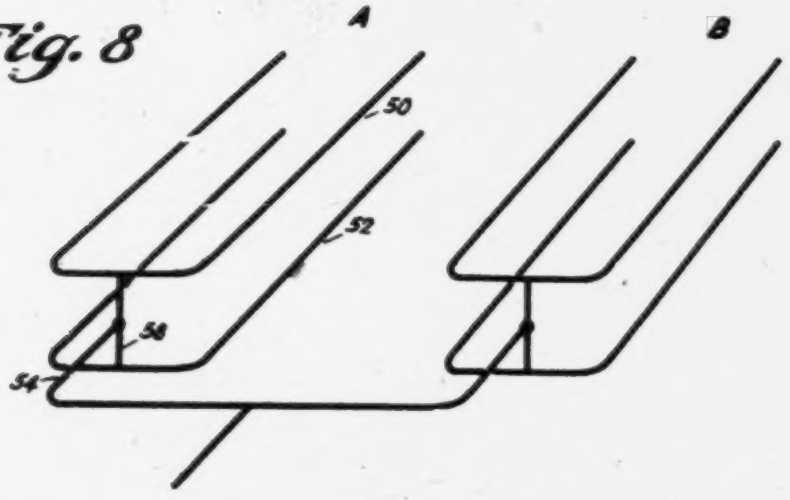


Fig. 9

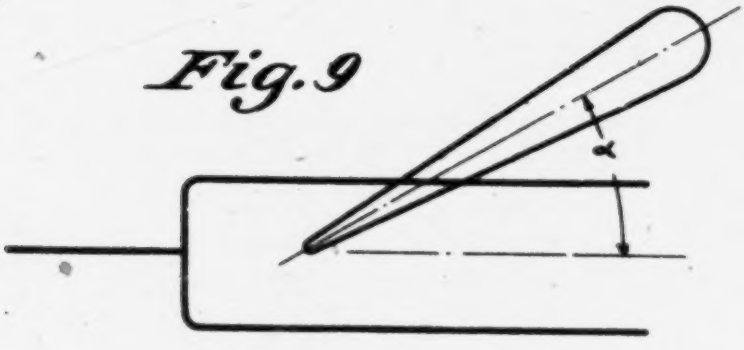
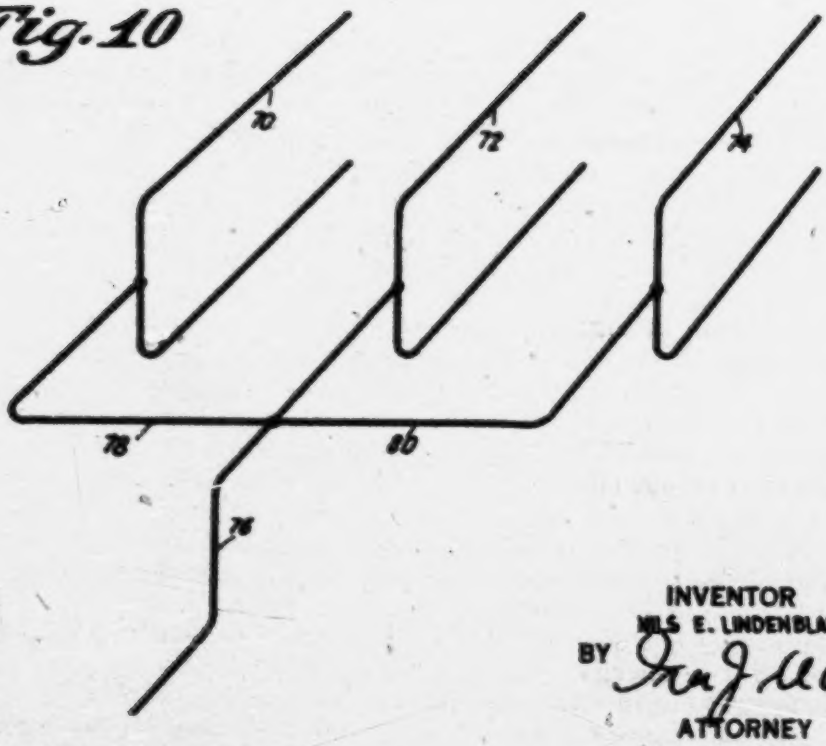


Fig. 10



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UNITED STATES PATENT OFFICE

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ANTENNA

Application filed September 7, 1928. Serial No. 304,445.

This invention relates to antennæ, and more particularly to directional antennæ for the propagation or reception of short wave signals.

Several types of beam and projector antenna systems for short waves have been developed, but these are rather complicated in structure and therefore relatively expensive to erect and adjust, and also are structurally suitable only for the wave length for which they have been designed and built. It is the primary object of my invention to provide a simplified antenna which will be capable of accommodating a broad range of wave lengths, and to this end I have experimented very extensively with the problem of radiation from transmission lines, as a result of which I have devised an antenna consisting merely of simple linear conductors. The antenna is suitable both for transmission and reception, but for simplification I shall refer to transmission in the description which follows. Identical structure and theory may be applied to reception.

If a standing wave is caused on a linear conductor which is long, relative to the working wave length, the conductor may be considered as composed of successive half wave length linear oscillators connected end to end, in which case there will be no summation of energy nor radiation in an end-on direction because each of the half wave oscillators does not radiate along its axis. Furthermore, there is no radiation at right angles to the wire because although each half wave length oscillator might tend to radiate in this direction, the successive half wave length radiators are opposed in phase, so that at a distance from the wire the average effect is zero. However, there is radiation in a direction intermediate the normal and longitudinal directions, and with a single conductor, this radiation takes place in the form of hollow cones having common axes in the wire.

This is wasteful of energy, and one object of my invention is to reduce the conical radiation so that it will consist only of concentrated lobes having axes in one plane. This is accomplished by providing two collaterally spaced substantially parallel linear conductors which are long, relative to the working wave length, and which are coupled in phase opposition. Because of the opposed phase relation in the two conductors there is substantially no radiation normal to the plane of the conductors, that is, by spacing them apart the radiation from the pair of conductors is concentrated, essentially, into conjugate pairs of oppositely directed lobes the axes of which lie in the plane of the conductors.

This arrangement, too, is wasteful of energy, and it is a further object of my invention to strengthen the radiation in one pair of opposite critical directions, while weakening the radiation in the conjugate pair of opposite critical directions, which I do by staggering the pair of wires, longitudinally, so that their ends make an angle with the transverse axis of the antenna equal to the critical angle of radiation, that is, the angle which the principal lobes of the radiation pattern of the antenna make with the longitudinal axis of the antenna. In this manner radiation in one pair of opposite directions from each of the conductors come on the same wave front at the same time, but being opposite in phase, they neutralize and cancel each other. In the conjugate directions, owing to the physical displacement of the conductors, the radiated energy tends to add. To make this addition a maximum it is desirable that the added energies be combined exactly in phase, and to provide for this the spacing of the pair of wires should be such that their distance apart, measured in the direction of radiation, is an odd number of half wave lengths.

The radiation has so far been reduced to a bidirectional radiation, and a further object of my invention is to make it unidirective, for which purpose I provide another pair of simple linear conductors arranged to form another antenna such as I have already described, spaced apart from the first antenna an odd number of quarter wave lengths in the direction of desired propagation, and energized in phase quadrature so that the entire system is made unidirective.

Instead of forced feeding of energy to the

second antenna a pure reflector action may be employed, in which case only one of the pairs of conductors is energized, in the case of a transmitter, or connected to the receiving set, in the case of a receiver, while the other pair of conductors is properly tuned and spaced and staggered so as to provide reflector action by reason of the energy transferred thereto from the other pair of conductors.

It has already been mentioned that the use of a pair of conductors causes the radiation to lie more nearly in a single plane, and in order to improve this characteristic a number of stories of antennæ, such as I have already described, may be employed, each antenna consisting of conductors lying in a single plane, while the various antennæ lie in vertically spaced parallel planes, and are coupled together so as to operate electrically in parallel. The spacing of these planes may be any spacing desired, particularly if a large number is used, but should preferably be a half wave length, especially when only two antennæ are used.

To sharpen the directivity in azimuth a number of antennæ may be used which are spaced apart in a horizontal direction, so as to present a broadside array.

A further object of my invention is to elevate the propagated wave, and this may be done either by arranging the antenna system with the linear conductors spaced apart in a horizontal direction, but with their plane tilted upwards in the direction of desired propagation, or by arranging all of the conductors so that they lie in a vertical plane, and are spaced apart vertically, and either lie horizontally in said plane, or at such an angle with the horizontal that the wave is propagated at the desired elevation. To then sharpen the directivity in azimuth a number of such antennæ lying in horizontally spaced vertical planes may be used.

The invention is described more in detail in the following specification, which is accompanied by drawings in which

Figures 1 and 2 are explanatory of my invention;

Figure 3 represents my antenna in simplest form;

Figure 4 represents a bidirective antenna constructed in accordance with my invention;

Figure 5 is a unidirective antenna employing an energized reflector;

Figure 6 is a unidirective antenna employing a tuned reflector;

Figure 7 is a modification of Fig. 5;

Figure 8 indicates schematically an antenna system employing a plurality of antennæ spaced vertically and horizontally to increase directivity in elevation and in azimuth, respectively;

Figure 9 is a schematic representation of an antenna and reflector lying in a vertical plane to obtain elevated radiation; and

Figure 10 indicates schematically a broadside aray of antennæ lying in vertical planes to increase the directivity in azimuth.

In Figure 1 there is shown a simple linear conductor 2 a half wave in length. The maximum radiation from this conductor takes place normally of the conductor, the pattern, in section, being a figure 8 such as is indicated by the lobes 4 and 6.

When a conductor which is long, relative to the wave length, is employed, and a standing wave is caused thereon, the radiation normal of the conductor is opposed in phase in the successive half wave length portions of the conductor, and consequently there is no radiation normally of the wire. There is no radiation endwise of the wire because although in this direction radiated energy would add favorably, there is no radiated energy to be added. The radiation takes place in an intermediate direction, and the principal rediation is indicated in Figure 2, in which there is a long conductor 8, on which a standing wave is caused, and from this conductor radiation takes place in conical lobes, such as the lobes 10 and 12. It will be seen from the figure that these lobes are in the form of hollow cones having their apices adjacent and located in the conductor. In actual practice it should be kept in mind that there will be a number of different cones of various lesser magnitudes, and lying in different directions, relative to the longitudinal axis of the antenna, but for the sake of simplicity only the principal radiation is indicated, and its direction is indicated by the angle α.

Referring to Figure 3 it will be seen that there are a pair of long conductors 14 and 16, and that these are substantially parallel and collaterally spaced. The conductors are connected in phase opposition to the transmitter 20 through tuning reactances 22, the latter being adjusted to cause standing waves on the conductors 14 and 16 by making the total electrical length of the circuit around the two wires a whole number of half wave lengths. This number should be odd, in order that the open ends of the conductors may be opposite in polarity. It should be noticed that these wires preferably are left with open ends, as a simple expedient to favor the growth of standing waves. If the transmission line 24 which interconnects the transmitter and the antenna is long, so that standing waves thereon might tend to cause undesired radiation, the transmission line may be closed with an impedance matching device 26, so that standing waves exist only between the device 26 and the antenna, and not on the line 24.

In a direction normal to the plane of the conductors 14 and 16 radiation is cancelled because of the phase opposition of the energy

in the conductors, and consequently the hollow cones of radiation indicated in Figure 2 are reduced to four ears or lobes, the axes of which lie in the plane of the conductors. These lobes may be grouped into the oppositely directed lobes 30 and 32, and a conjugate pair of oppositely directed lobes 34 and 36. The direction of radiation here also makes an angle α with the longitudinal axis of the antenna.

Referring to Figure 4 it will be seen that the arrangement there disclosed is quite similar to that shown in Figure 3 except that the conductors 14 and 16 have been staggered, longitudinally, so that their ends make an angle α with the transverse axis of the antenna. This causes the radiation corresponding to the lobes 34 and 36 in Figure 3 to come on the same wave front at the same time, and being opposed in phase, the radiation is practically cancelled, making the antenna bidirective, in the direction of the lobes 30 and 32, which are correspondingly strengthened, for radiation in this direction is additive, owing to the displacement of the conductors. The transverse spacing of the conductors is indicated by the dimension D, and should be such, preferably, that when multiplied by the cosecant of the angle of radiation α, the product will equal an odd number of half wave lengths, for in this case the radiation from the two conductors will combine exactly in phase.

It is slightly desirable, but not essential, that the spacing D be one or more whole wave lengths, in which case radiation transversely of the antenna will be effectually prevented, but this condition can only be met for certain special cases of the angle α, and is not important, owing to the fact that each wire is essentially non-radiative in a normal direction.

Referring now to Figure 5 it will be seen that there are two pairs of collaterally spaced conductors, 14, 16 and 114, 116, and each of these pairs is arranged in accordance with the principles set forth in connection with Figure 4. The pairs of antennæ are energized in parallel through a branched transmission line system, and the feed is made such that the antennæ are energized in phase quadrature. This may be obtained most simply by having the arms of the branched transmission line differ in length by an odd number of quarter wave lengths, as has been indicated in the drawings, this difference in length being introduced ahead of the impedance matching devices, so that it exists in lines on which there is a travelling wave, rather than a standing wave. The pairs of conductors are spaced apart a distance d, and this distance is such that when multiplied by the cosecant of the angle of principal radiation α, the product will be an odd number of quarter wave lengths, so that owing to the initial phase difference in the energization of the antennæ, the radiated energy in one of the opposite directions, as 30, adds, while in the opposite direction the energies are opposed, and cancel, thereby making the antenna unidirective, instead of bidirective.

The arrangement shown in Figure 5 employs an energized or forced feed reflector, which may be called a director, but it is also possible to use a simple tuned reflector energized from the other pair of conductors. In this case it is desirable to have the reflector near the energized conductors, and in such case the arrangement preferably is slightly modified as in Figure 6, in which the pair of conductors 14 and 16 corresponds to the similarly numbered pair in the preceding figures, while the appropriate reflector wires are numbered 214 and 216. As before, the ends of the conductors 14 and 16 are staggered so as to make an angle α with the transverse axis of the antenna, and the same applies to the reflecting conductors 214 and 216. Also, as before, the distance D is so chosen that when multiplied by the cosecant of the angle α the product will equal an odd number of half wave lengths, so that radiation in the direction of stagger will be added as nearly as possible in phase, and furthermore, the distance D may, if desired, be made one or more whole wave lengths. The conductors 14 and 16 are energized in phase opposition from a transmitter 20, and if desired, an impedance matching device 26, and tuning means 22, may be employed. The conductors 214 and 216 are coupled in phase opposition, and are provided with a tuning means 222, here illustrated as a trombone slide, so that the reflector may be tuned to favor the production of standing waves.

The problem of the spacing and of the stagger of the reflector conductors, relative to the conductors 14 and 16, is not so simple as in the preceding case. If energy were induced in the conductor 216, from the conductor 16, only along the line of direction of principal radiation, as indicated by the dotted arrow 40, the rule would be to make this distance a quarter wave, so that the reflected energy would combine in phase with the energy radiated from the conductor 16 in one direction, and out of phase in the opposite direction. The situation is complicated by the fact that energy is induced in the conductor 216 from the conductor 16 along the shorter normal path, indicated by the arrow 42, and from the conductor 14, indicated by the arrow 44, so that the phase and magnitude of the current in the reflector is the resultant of several factors. The best arrangement may be found by experiment, and stated in a general fashion, the rule is that the spacing and stagger should be such that the effective electrical spacing is a quarter wave, while the reflected energy

comes on the original wave front a quarter wave later.

In Figure 7 there is an energized director 114, 116, as in Fig. 5, but the spacing d between the antenna and the director antenna is made less than the spacing D between the conductors of the antennæ as in Fig. 6. Another feature of this modification is the use of the trombone slides 46 and 48 to tune the antennæ. This tuning need not be great in range, though the antenna structure will cover a great wave length range, because the adjustment can be made for a different number of half waves in length, whenever necessary to accommodate a desired wave length. The transmitter 20 is coupled to the antennæ through a transmission line 24, which is coupled to the trombone slide 46 at points so spaced that the impedance of the line is matched. The trombones 46 are interconnected by a line 90, the ends of which are coupled to the trombone slides at points so spaced that the impedance of the line is matched, so that there is a travelling rather than a standing wave on the line. In this manner the line may be used to introduce a phase change, and is made one, three or five etc., quarter waves in length to obtain phase quadrature in the antennæ. Three meters, 92, are inserted along a quarter wave portion of the line, and are made to read alike when the line is properly adjusted.

The conductors 114 and 116 are lengthened by the addition of the loops 94 and 96, so as to equal the conductors 14 and 16 in length. With this precaution the antennæ should both take equal current. Ammeters 98, shunted to the trombone slides 46, are made to read alike, and at a maximum, when the antenna is properly adjusted.

In connection with Figure 3, and the succeeding figures, it has been pointed out that the radiation takes place principally in the plane of the conductors, and in order to sharpen this characteristic antennæ, such as have already been described, may be located above one another in parallel planes, so as to make a multiple storied antenna. This has been indicated in A, of Figure 8, in which an entire antenna, consisting of a pair of conductors, and either an energized or non-energized pair of reflecting conductors, properly staggered, and lying in a single plane, is schematically indicated by the U shaped line 50. Another such antenna system, lying in a parallel plane, is indicated at 52, and these are fed electrically in parallel through a branched transmission line system, schematically indicated by the single lines 54, 56 and 58. The spacing should preferably be a half or odd number of half wave lengths, so as to provide complete cancellation in an up and down direction. With this type of antenna the structure is arranged at an angle α, in azimuth, relative to the direction in which radiation is desired. If it is desired to sharpen the directivity in this direction, i. e. in azimuth, a plurality of antennæ may be arranged in broadside, and fed cophasially, as is indicated by the antenna systems A and B in Fig. 8. If elevated radiation is desired, the planes in which each antenna lies must be correspondingly tilted or elevated away from a truly horizontal direction. The antennæ so far described provide horizontal polarization.

By positioning the plane of an antenna consisting of two pairs of conductors, such as has already been described in connection with Figures 5, 6, and 7, in a vertical plane, as is indicated in Figure 9, radiation with vertical polarization may be provided. In this case the antenna is directed in the direction of desired propagation in azimuth, and the angle α provides the angle of elevation. This arrangement is desirable because the elevated radiation is obtained without the expense of an elaborate supporting structure for holding the antenna at the corresponding angle. Slight changes in the angle of elevation may be made by slightly changing the position of the conductors, relative to the horizontal, while keeping them in a vertical plane.

In order to sharpen the directivity in azimuth a number of antennæ, located in parallel planes, may be provided as has been indicated in Figure 10, in which each of the antennæ 70, 72, and 74 is an antenna such as has been described in either of Figures 5, 6, or 7, and the various antennæ are energized electrically in parallel through a branched transmission line system 76, 78, 80. The branches are so arranged that the antennæ are energized cophasially, and they are preferably spaced a half wave apart, but may be at any spacing, especially when a considerable number antennæ are employed. This antenna system propagates a vertically polarized elevated wave.

Over a considerable range of tuning the angle α remains quite constant. Only by changing the wave length so greatly that the character of the long wire is completely changed so as to be a relatively few instead of many waves in length, does that lobe of radiation which is greatest in magnitude shift or jump from one to another, so as to definitely and considerably change the angle of radiation α. For example, using conductors approximately eight mean waves in length I have varied the tuning from about five to seven meters without appreciably changing the angle of radiation. The antenna is tuned, but the antenna structure itself need not be changed. The tuning is small in amount because it is needed only to bring the total electrical length to the nearest odd number of half waves, rather than to a fixed length.

I claim:

1. A directional antenna comprising a collaterally spaced pair of simple linear conductors adapted to have standing waves formed thereon which are long, relative to the working wave length, and means energizing said conductors in phase opposition at adjacent ends of said conductors, said conductors lying on the same side as said energizing means and extending away from said energizing means whereby radiant action occurs predominantly in a direction making equal angles greater than zero degrees with reference to said conductors.

2. A directional antenna comprising a collaterally spaced pair of substantially parallel simple linear conductors adapted to have standing waves formed thereon which are long, relative to the working wave length, and means energizing said conductors in phase opposition, said conductors lying on one side of and extending away from said energizing means, radiant action occurring predominantly in a direction making equal angles greater than zero degrees with reference to said conductors.

3. A directional antenna comprising a collaterally spaced pair of substantially parallel simple linear conductors which are long, relative to the working wave length, means coupling said conductors in phase opposition, and means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors.

4. A directional antenna comprising a collaterally spaced pair of simple linear conductors which are long, relative to the working wave length, and which are so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, and means coupling said wires in phase opposition.

5. A directional antenna comprising a collaterally spaced pair of substantially parallel simple linear conductors which are long, relative to the working wave length, and which are so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling said conductors in phase opposition, and means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors.

6. A directional antenna comprising two pairs of collaterally spaced simple linear conductors all lying in the same plane, the conductors in each of said pairs of conductors being long, relative to the working wave length, and so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, said pairs of conductors being so staggered and spaced apart in the direction of principal radiation as to make the antenna unidirectional, means coupling the pairs of conductors in phase opposition, and means coupling at least one of the pairs of conductors with radio equipment.

7. A directional antenna system comprising two pairs of collaterally spaced and substantially parallel simple linear conductors all lying in the same plane, each conductor being long, relative to the working wave length, the conductors in each pair being so staggered, longitudinally that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so spaced apart in the direction of principal radiation as to make the antenna unidirective, and means coupling at least one of the pairs of conductors with radio equipment.

8. A directional antenna system comprising two pairs of collaterally spaced and substantially horizontally parallel simple linear conductors all lying in the same vertical plane, each conductor being long relative to the working wave length, the conductors in each pair being so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so spaced apart in the direction of desired radiant action as to make the antenna unidirective, and means coupling at least one of the pairs of conductors with radio equipment.

9. A directive transmission system comprising two pairs of collaterally spaced simple linear conductors all lying in the same plane, the conductors in each of said pairs of conductors being long, relative to the working wave length, and so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, said pairs of conductors being so staggered and

spaced apart in the direction of principal radiation as to make the antenna unidirectional, means coupling the pairs of conductors in phase opposition, a radio transmitter for energizing the conductors, and means coupling the transmitter to at least one of the pairs of conductors in phase opposition.

10. A directive transmission system comprising two pairs of collaterally spaced and substantially parallel simple linear conductors all lying in the same plane, each conductor being long, relative to the working wave length, the conductors in each pair being so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so spaced apart in the direction of principal radiation as to make the antenna unidirective, a radio transmitter for energizing the conductors, and means coupling the transmitter to said pairs of conductors in phase quadrature.

11. A directional antenna system including a plurality of unidirectional antennæ lying in spaced parallel planes, each antenna comprising two pairs of collaterally spaced and substantially parallel simple linear conductors lying in a single plane, the conductors being long, relative to the working wave length, the conductors in each of said pairs being so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so staggered and spaced apart in the direction of principal radiation as to make the antenna unidirectional, and means coupling corresponding pairs of conductors in each of the antennæ in parallel and in proper phase to radio equipment.

12. A unidirectional antenna system including a plurality of unidirectional antennæ lying in spaced parallel vertical planes, each antenna comprising two pairs of collaterally spaced and substantially horizontal parallel simple linear conductors lying in a single plane, said planes being spaced transversely of the antenna so as to sharpen the directivity in azimuth, the conductors being long relative to the working wave length, the conductors in each of said pairs being so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so staggered and spaced apart in the direction of principal radiation as to make the antenna unidirectional, and means coupling corresponding pairs of conductors in each of the antennæ in parallel and in proper phase to radio equipment.

13. A directive transmission system including a plurality of unidirective antennæ lying in spaced parallel planes, each antenna comprising two pairs of collaterally spaced and substantially parallel simple linear conductors lying in a single plane, the conductors being long, relative to the working wave length, the conductors in each of said pairs being so staggered, longitudinally, that radiation in one pair of opposite critical directions is strengthened, while radiation in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so staggered and spaced apart in the direction of principal radiation as to make the antenna unidirectional, a radio transmitter for energizing said antennæ and means coupling corresponding pairs of conductors in each of said antennæ in parallel and in proper phase to the radio transmitter.

14. A unidirectional short wave antenna comprising four collaterally spaced substantially parallel wires which are long, relative to the working wave length, all lying in a single plane, means for coupling pairs of the wires in phase opposition, means for tuning the pairs of wires to an odd number of half waves in total electrical length so as to cause standing waves of opposite polarity thereon, the wires in each pair being staggered longitudinally so that their ends form the same angle, relative to the transverse axis of the antenna, that the direction of principal radiation makes with the longitudinal axis of the antenna, and spaced apart an odd number of half wave lengths in the direction of principal radiation, the pairs of conductors being so staggered and spaced apart that energy from one pair combines with the energy from the other pair in phase so as to make the antenna unidirectional,

and radio equipment coupled to at least one of the pairs of conductors.

15. A unidirectional short wave antenna comprising four collaterally spaced substantially parallel wires which are long, relative to the working wave length, all lying in a single plane, a pair of trombone slides for coupling together pairs of the wires and for tuning them to an odd number of half waves in total electrical length so as to cause standing waves of opposite polarity thereon, the wires in each pair being staggered longitudinally so that their ends form the same angle, relative to the transverse axis of the antenna, that the direction of principal radiation makes with the longitudinal axis of the antenna, and spaced apart an odd number of half wave lengths in the direction of principal radiation, the pairs of conductors being spaced apart a quarter wave length in the direction of principal radiation, a transmission line a quarter wave in length coupled to the trombone slides at points so spaced that the impedance therebetween matches the impedance of the transmission line, and radio equipment coupled to one of the trombone slides.

16. The method of securing unidirectional electro-magnetic wave propagation which includes producing a standing wave, producing another physically shifted standing wave of opposite polarity, and combining the fields produced by the standing waves whereby propagation of electro-magnetic energy is unidirectional.

17. A directional antenna comprising a collaterally spaced pair of simple linear conductors which are long, relative to the working wave length, and which are so staggered, longitudinally that wave action in one pair of opposite critical directions is strengthened, while wave action in the conjugate pair of opposite critical directions is weakened, and means for energizing said wires in phase opposition.

18. A directional antenna comprising a collaterally spaced pair of simple linear conductors which are long relative to the working wave length, and which are so staggered, longitudinally, that electromagnetic action in one pair of opposite critical directions is strengthened, while electromagnetic action in the conjugate pair of opposite critical directions is weakened, said wires adapted to be energized in phase opposition.

19. A unidirectional antenna comprising spaced linear conductors, means for causing standing waves of different polarity thereon, said conductors being staggered whereby action of the antenna is predominately unidirectional.

20. A directional antenna comprising a collaterally spaced pair of substantially parallel simple linear conductors which are long, relative to the working wave length, and which are so staggered, longitudinally, that wave action in one pair of opposite critical directions is strengthened, while wave action in the conjugate pair of opposite critical directions is weakened, said conductors adapted to be energized in phase opposition, means for actionally coupling the conductors, and means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors.

21. A directional antenna comprising two pairs of collaterally spaced simple linear conductors all lying in the same plane, the conductors in each of said pairs of conductors being long, relative to the working wave length, and so staggered, longitudinally, that electro-magnetic action in one pair of opposite critical directions is strengthened, while electro-magnetic action in the conjugate pair of opposite critical directions is weakened, said pairs of conductors being so staggered and spaced apart in the direction of principal electro-magnetic action as to make the antenna unidirectional, means coupling the pairs of conductors in phase opposition, and means coupling at least one of the pairs of conductors with radio equipment.

22. A directional antenna system comprising two pairs of collaterally spaced and substantially parallel simple linear conductors all lying in the same plane, each conductor being long, relative to the working wave length, the conductors in each pair being so staggered, longitudinally, that radiant action in one pair of opposite critical directions is strengthened, while radiant action in the conjugate pair of opposite critical directions is weakened, means coupling the conductors in each pair in phase opposition, means for tuning said conductors and coupling means to an overall electrical length of an odd number of half waves, so as to cause standing waves of opposite polarity on the conductors in each pair, said pairs of conductors being so spaced apart in the direction of desired radiant action as to make the antenna unidirective, and means coupling at least one of the pair of conductors with radio apparatus.

23. A directional antenna comprising a pair of long linear wires connected at adjacent ends to high frequency apparatus and having standing waves of opposite instantaneous polarity thereon, said wires being several wave lengths in length and extending away from and on one side only of said adjacent ends.

24. A directional antenna system comprising a pair of long straight wires and means at adjacent ends of the wires for exciting the wires in phase opposition whereby standing waves of opposite instantaneous polarity are set up on the wires, said wires being several

wave lengths in length at the operating frequency and extending on one side only and away from said adjacent ends.

25. A directive antenna system for propagating or receiving propagated electromagnetic waves comprising a pair of substantially straight conductors, long, relative to the working wave length such that several standing waves at the operating frequency are set up on each conductor, said conductors being arranged so that radiant action occurs in a direction making the same angle with each conductor, and means coupling said conductors in phase opposition, said conductors lying in the same plane and extending away from said coupling means on one side only thereof.

26. A directive antenna system for propagating or receiving electromagnetic waves as claimed in claim 25 wherein a similar pair of conductors are provided, the conductors of said similar pair being arranged parallel to the respective conductors of the first pair whereby the directional effect of the system is augmented.

27. A directive antenna system for propagating or receiving electromagnetic waves as claimed in claim 25 wherein a similar pair of conductors are provided, the conductors of said similar pair being arranged parallel to the respective conductors of the first pair and lying in the same plane as the plane of the first pair whereby the directional effect of the system is augmented.

28. A directive antenna system for propagating or receiving electromagnetic waves as claimed in claim 25 wherein a similar pair of conductors are provided, the conductors of said similar pair being arranged parallel to the respective conductors of the first pair and lying in a plane parallel to the plane of said first pair whereby the directional effect of the system is augmented.

29. A directive antenna system for propagating or receiving propagated electromagnetic waves, comprising a plurality of pairs of conductors arranged in the same plane, respective conductors of the pairs being substantially parallel, each of said conductors being long relative to the working wave length and adapted to have a plurality of standing waves at the working wave length set up thereon, means for connecting the conductors of each pair in phase opposition, the conductors of each pair extending on one side only and away from said connecting means, and, a like number of pairs of conductors arranged in a plane parallel to the plane of said first mentioned plurality of pairs of conductors, the conductors in the like plurality of pairs being arranged parallel to the conductors of said first mentioned plurality of pairs, the conductors of said like pairs being coupled and arranged in a manner similar to the conductors of said first mentioned pairs of conductors, like conductors of the pairs being arranged in parallel fashion, whereby radiant action occurs predominantly in a direction making equal angles greater than zero degrees with each conductor of said system.

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[fols. 671-676] PLAINTIFF'S EXHIBIT No. 4

Sept. 19, 1933. N. E. LINDENBLAD 1,927,522

ANTENNA FOR RADIO COMMUNICATION

Filed Dec. 24, 1928

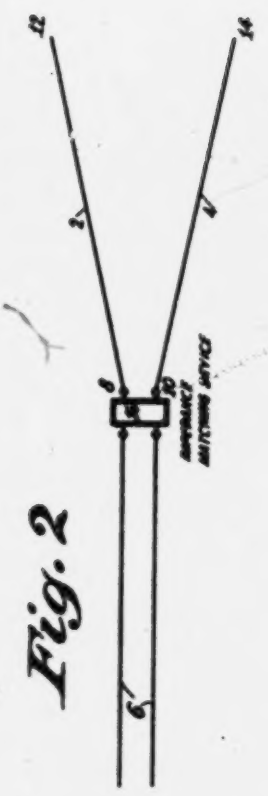


Fig. 2



Fig. 1

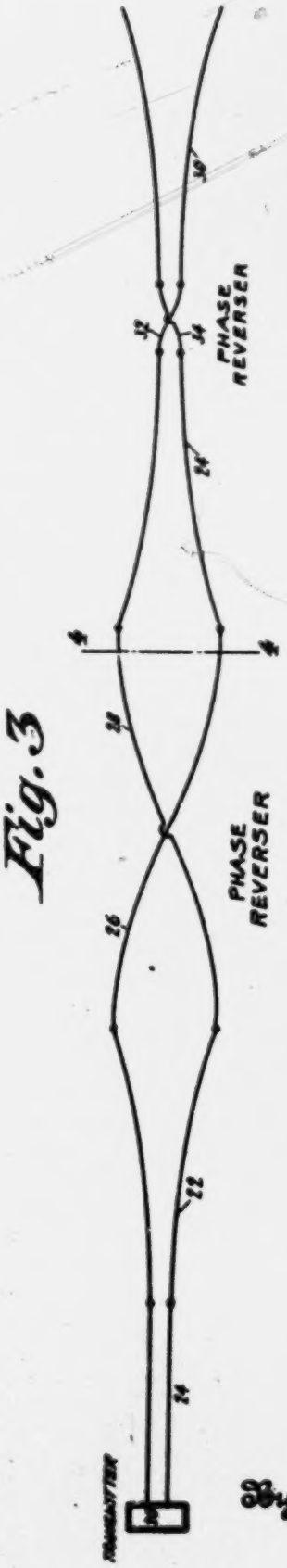


Fig. 3



Fig. 4

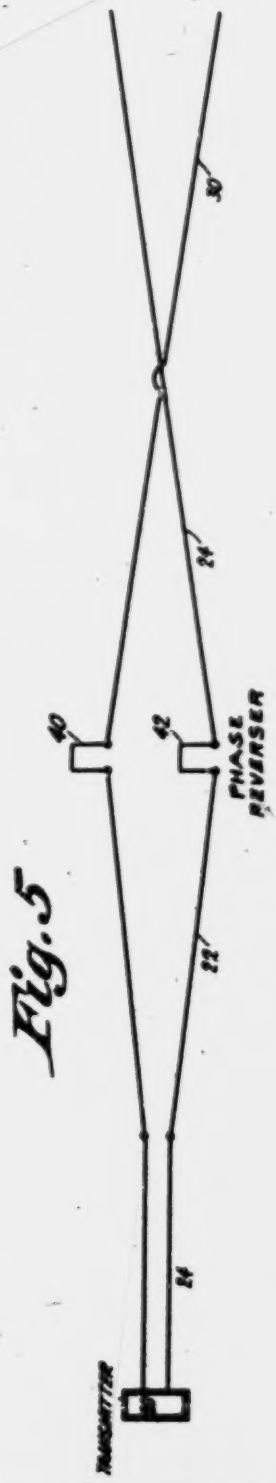


Fig. 5

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Patented Sept. 19, 1933 1,927,522

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1,927,522

ANTENNA FOR RADIO COMMUNICATION

Nils E. Lindenblad, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application December 24, 1928
Serial No. 328,147

24 Claims. (Cl. 250—33)

This invention relates to antennas for radio communication.

Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency, and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment. It is an object of my invention to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency, and a further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices.

My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and which gradually diverge to a much wider spacing at their other ends. In effect, therefore, the antenna consists merely of a gradually diverging extension of the conductors of the transmission line, and, in one aspect, the invention resides in the discovery that radiation may be obtained from a transmission line by gradually increasing the spacing between the wires of the line.

The desired radiation takes place in the direction of the axis of the pair of conductors, and is caused by the expansion of the current or the travelling wave of energy in the conductors. Reflection will cause a standing wave, instead of a travelling wave, and result in radiation sideways from the antenna. Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet. However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention. It is not feasible, in the case of a transmitting antenna, to avoid standing waves by closing the end of the antenna with a surge resistance, because of the excessive losses which would take place therein.

To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible. To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation, and on the other hand, to keep the same angle of divergence necessitates so wide a spacing as to make the antenna structurally inconvenient. To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively.

I have also found that a pair of converging conductors, like a pair of diverging conductors, will radiate energy, but this radiation is in opposite phase. The antenna may therefore comprise a plurality of pairs of conductors which successively diverge and converge, with means coupling the antennas which reverse the phase of the energy fed thereto.

While the terminology employed in the foregoing description may apply more particularly to a transmitting antenna the structure set forth is equally useful as a receiving antenna.

The invention is further described in the following specification, which is accompanied by a drawing in which

Figure 1 represents one form of my invention;

Figure 2 is a modification employing straight conductors;

Figure 3 shows the use of a plurality of diverging and converging antennas;

Figure 4 is a section of Figure 3 taken on the line 4—4; and

Figure 5 is a modification of Figure 3 showing an alternative form of phase reversing coupling means between the successive antennas.

Referring to Figure 1 it will be seen that the antenna consists of a pair of conductors 2, 4, which are connected to a transmission line 6 at points 8 and 10, which are spaced at the spacing of the transmission line. From the points 8 and 10 the conductors 2 and 4 gradually diverge to a much wider spacing at the ends 12 and 14. The extension of the conductors may be curved, as shown, and one form which is quite successful in operation is an expansion according to an exponential law.

However, in actual practice I find that the refinement of an exponential curve is not essential, and that the conductors 2 and 4 may be straight conductors strung between the points 8 and 12, and the points 10 and 14, under direct tension, and without the use of intermediate shaping or guy wires, and such an arrangement has been indicated in Figure 2.

No impedance matching device is necessary with this antenna, so that in actual practice the antenna is exceedingly simple to erect, it being necessary merely to provide a pair of supporting points 12 and 14 at a desired distance from the termination of the transmission line, and then to continue the conductors of the transmission line directly to the spaced points 12 and 14.

Whatever amount of energy has not been radiated when the travelling wave reaches the end of the antenna is reflected, and thus causes a partial standing wave, which will extend back along the transmission line 6. If the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may prove desir-

able to employ an impedance matching device between the transmission line and the antenna, as is indicated by the impedance matching unit 16, shown in Figure 2.

If, instead, the antenna is made to radiate more energy, the standing wave will incidentally be reduced, and the impedance matching device may be dispensed with. To merely make the antenna much longer, while keeping the same spacing at its open end, does not help, because such a procedure merely slows up the rate of spread of the energy, and does not increase the quantity of energy radiated. On the other hand it ordinarily is not structurally possible to make the antenna considerably longer while maintaining the same angle of divergence of the conductors, owing to the great spacing which would be needed at the open end of the antenna. The same result may be accomplished without these disadvantages by using a plurality of antenna sections arranged end to end. Since a converging antenna is similar in operation to a diverging antenna, except for a reversal in phase, it becomes especially convenient to use a plurality of antenna sections which are successively diverging and converging, and such antennas have been indicated in Figures 3 and 5.

Referring to Figure 3 it will be seen that a transmitter 20 is coupled to a diverging antenna 22 by a transmission line 24. The diverging antenna 22 is followed by a converging antenna 24, which is coupled to the diverging antenna 22 by a pair of conductors 26 and 28. The spacing between these conductors is kept constant, so that practically no radiation takes place therefrom, but at the same time the conductors are electrically crossed in order to reverse the phase of the energy being fed from antenna 22 to antenna 24. For this purpose each of the conductors is supported, at least approximately, in the form of a helix, a feature which is more clearly indicated in the section taken on the line 4—4, and constituting Figure 4. The pitch of the helices should be sufficiently great that the physical distance in space between the antennas 22 and 24 is substantially equal to the distance along the conductors 26 and 28, so that the phase displacement of the wave travelling in space will coincide with that of the energy wave travelling on the conductors 26 and 28. The converging antenna 24 is followed by a diverging antenna 30, and the adjacent ends of the antennas 24 and 30 are coupled by phase reversing coupling conductors 32 and 34.

A modification of the arrangement shown in Figure 3 is indicated in Figure 5, in which a transmitter 20 is coupled by a transmission line 24 to a diverging antenna 22, followed by a converging antenna 24, which in turn is followed by a diverging antenna 30, much as in Figure 3. However, in this case the antennas 22 and 24 are coupled by conductors 40 and 42, which are a half wave in length, in order to reverse the phase of the energy flowing therethrough, and which are bent back upon themselves so as to be substantially nonradiating. The connection between the antennas 24 and 30 is made simply by crossing the conductors as shown, the conductors being separated slightly at the crossing point by an insulator in order to prevent a short circuit between the conductors. In the arrangements shown in Figures 3 and 5 any desired number of antenna sections may be employed.

The plane of polarization of the radiated energy coincides with the plane of the conductors, so that if the conductors are positioned in a horizontal plane the energy is radiated with horizontal polarization, and if the conductors are positioned in a vertical plane the energy is radiated with vertical polarization.

With the conductors in a horizontal plane a standing wave tends to cause side radiation. By locating the conductors in a vertical plane the directivity in azimuth may be maintained regardless of the presence of standing waves, but even in such case it is desirable to prevent waste of the energy radiated thereby, and it is therefore desirable to make the length of the conductors or the number of antenna sections sufficiently great, in accordance with the foregoing instruction, to reduce the standing wave.

In connection with Figures 3 and 5, the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground; we will then have two serially connected conductors (conductor 26 and the upper antenna leading to transmission line 24 in Figure 3). Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors.

It will be understood by those skilled in the art that if improved directivity is desired a plurality of these antennas may be employed abreast or in broadside, that is to say, collaterally spaced apart in parallel formation along a line at right angles to the desired direction of communication.

Since the preferred radiation is from the travelling wave, and is due to the expansion of the lines of force between the current charges travelling along the conductors, the divergence should preferably be fairly gradual, and the spacing at the open end, while variable over a great range, should be in the neighborhood of a fifth of the length, and the length of each antenna section should be of the order of magnitude of five to ten waves long.

The antenna is equally suitable both for transmission and reception, the energy in the latter case being collected and converged into the transmission line without the necessity of an impedance matching device.

I claim:

1. The method of directively radiating or collecting high frequency electrical energy which includes directing energy of opposite polarity in a plurality of gradually diverging paths diverging and extending longitudinally in the desired direction of radiant action.

2. The method of unidirectionally radiating or collecting high frequency electrical energy which includes directing energy of opposite polarity in a plurality of gradually converging paths converging and extending longitudinally in the desired direction of radiant action.

3. The method of radiating or collecting high frequency electrical energy which includes directing energy of opposite polarity successively in a plurality of gradually diverging and converging paths and phase reversing the energy as it is directed from one path into another.

4. A uni-directional antenna comprising a gradually diverging pair of conductors excited in phase opposition, diverging and extending longitudinally only in the desired direction of radiant action.

5. A uni-directional antenna comprising a gradually converging pair of conductors excited in phase opposition, converging and extending longitudinally only in the desired direction of radiant action.

6. A uni-directional antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the desired direction of radiant action, the effective portions of which gradually diverge and converge successively.

7. A uni-directional transmitting antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the direction of desired transmission, the radiating portions of which gradually diverge and converge successively in the direction of desired transmission.

8. In combination, a two conductor transmission line excited in phase opposition, and an antenna connected thereto extending longitudinally in the direction of transmission, comprising a gradually diverging extension of the conductors of the transmission line at their remote open ends.

9. In combination, a two conductor transmission line excited in phase opposition, and an antenna extending longitudinally in the direction of desired radiant action comprising an open ended pair of conductors which at one end are spaced at the spacing of the transmission line and are coupled thereto, and which gradually diverge to a much wider spacing at their open ends.

10. In combination, a transmission line, and an antenna extending longitudinally in the direction of desired radiant action connected thereto comprising a pair of open ended conductors of the order of magnitude of a number of wave lengths long which are widely spaced at the ends remote from the transmission line and energized with energy of opposite polarity, and spaced at the spacing of the transmission line at their junction therewith.

11. A uni-directional antenna comprising a plurality of pairs of gradually diverging conductors extending longitudinally in the direction of desired transmission and energized in phase opposition.

12. In combination, a transmission line, an antenna connected thereto comprising a pair of conductors a number of wave lengths long which are spaced at the spacing of the transmission line at their junction therewith, and which gradually diverge to a much wider spacing at their remote ends, a second antenna comprising a pair of conductors a number of wave lengths long arranged in extension of the first antenna, and widely spaced at their near ends and closely spaced at their remote ends, another diverging antenna arranged in extension of the converging antenna, and phase reversing means for coupling said antennas together.

13. A uni-directional antenna comprising a diverging pair of conductors excited in phase opposition, diverging only in the desired direction of radiant action.

14. A uni-directional antenna comprising a converging pair of conductors excited in phase opposition, converging only in the desired direction of radiant action.

15. A uni-directional antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the desired direction of radiant action, the effective portions of which diverge and converge successively.

16. A highly directional antenna system comprising wires which are long relative to the length of the communication wave excited in phase opposition, which first diverge from the excitation end and then converge successively, whereby radiant action occurs predominantly in a direction substantially through the opposite apices of the wires.

17. A system in accordance with claim 16, characterized in this, that said wires are in a single vertical plane.

18. A highly directional antenna system comprising a pair of conductors excited in phase opposition, said wires being long relative to the length of the communication wave and extending in the desired direction of radiant action, the effective portions of which diverge and converge successively.

19. A highly directional antenna system comprising a pair of conductors angularly disposed with respect to each other, said conductors being long relative to the length of the communication wave and open-ended, and means for exciting the conductors in phase opposition whereby radiant action occurs predominantly along the direction of the axis of the conductor system.

20. A unidirectional antenna system comprising a diverging pair of conductors, the said conductors being long relative to the length of the communication wave, and means for producing traveling waves thereon whereby radiation is predominantly along the approximate direction of the length of the conductor system.

21. A system in accordance with claim 20 characterized in this, that said conductors are open-ended and disposed in the same vertical plane.

22. A directional antenna comprising a diverging pair of conductors which are long relative to the working wave length, and means at adjacent ends of said conductors for energizing same in phase opposition, said conductors being arranged to be on the same side of said energizing means and to extend away from said energizing means whereby radiant action occurs predominantly along the approximate direction of the length of the conductor system.

23. A directional antenna comprising a pair of open-ended, diverging conductors which are long relative to the working wave length, and means at adjacent ends of said conductors for energizing same in phase opposition, said conductors being arranged to be on the same side of and to extend away from said energizing means whereby radiant action occurs predominantly in a direction making equal angles greater than zero degrees with reference to said conductors.

24. A highly directional antenna system comprising a pair of electrical conductors which are disposed at an angle with respect to each other and serially connected together, said conductors having an overall length which is long relative to the operating wave length, high frequency apparatus, and means for connecting said apparatus to one end of one of said conductors, the other end of said connected conductor being connected to one end of the second conductor of said pair whereby high frequency energy flows through the entire length of one conductor and continues serially through the entire length of the other conductor, the conductors being adjusted in length and impedance so that radiant action occurs principally in the direction of a line perpendicular to the bisector of the angle between said conductors.

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[fols. 677-692] PLAINTIFF'S EXHIBIT No. 5

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Fig. 1a

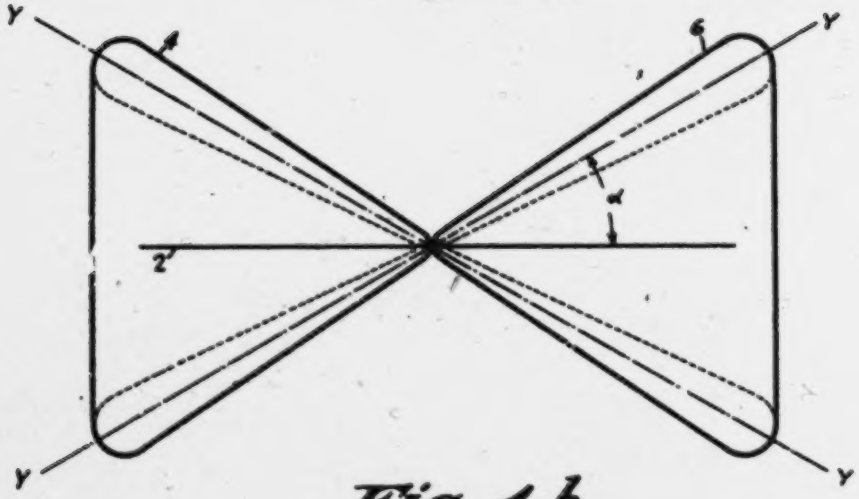


Fig. 1b

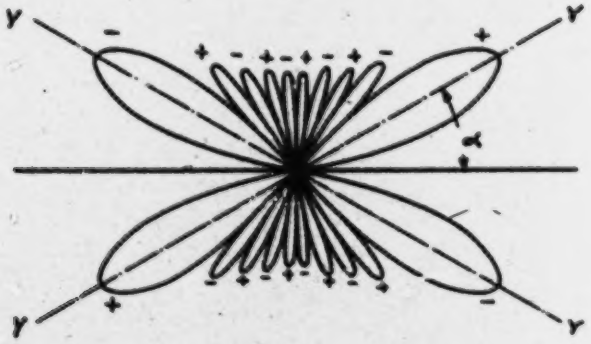


Fig. 2b

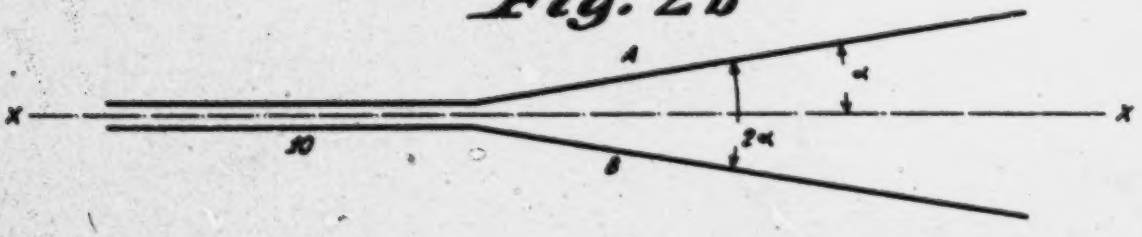


Fig. 2a

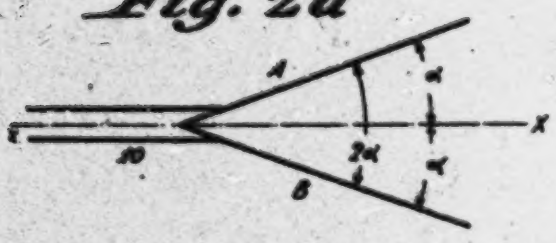
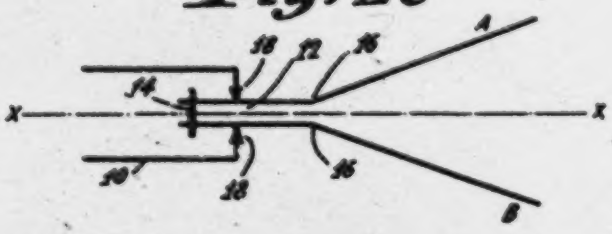


Fig. 2c



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Fig. 3

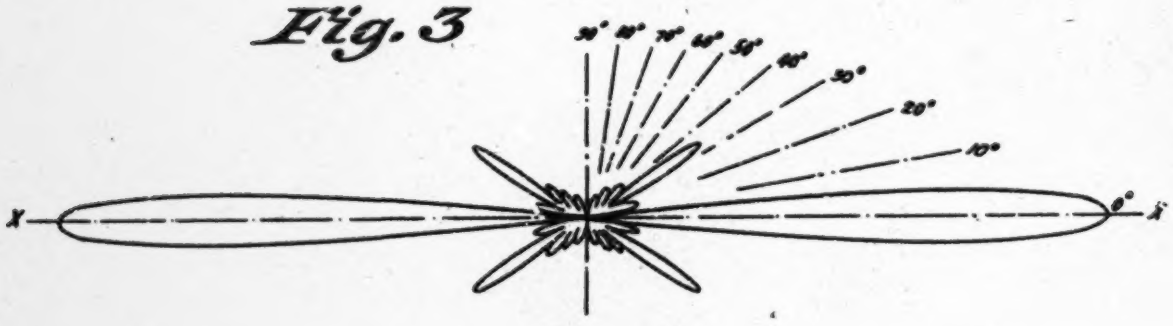


Fig. 4

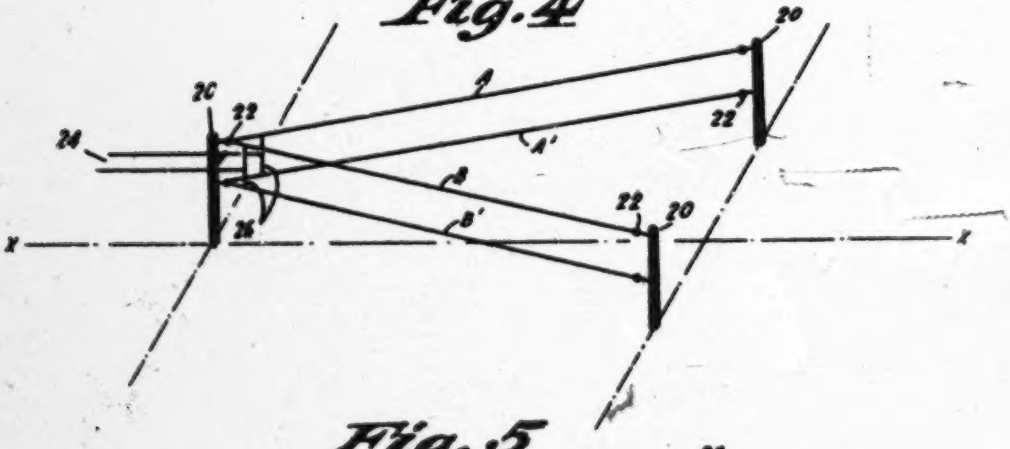


Fig. 5

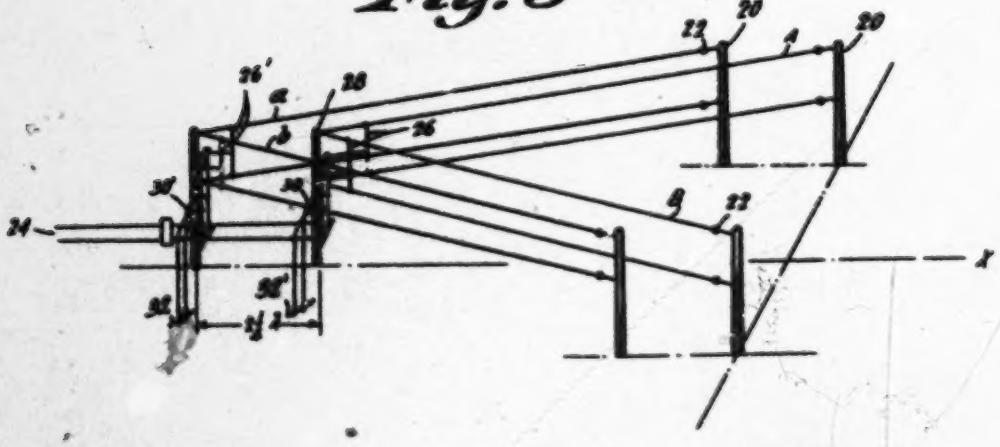
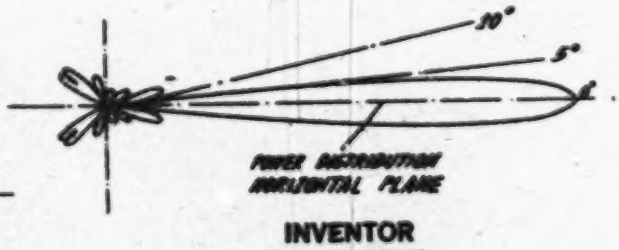


Fig. 6



POWER DISTRIBUTION HORIZONTAL PLANE

Fig. 7



POWER DISTRIBUTION VERTICAL PLANE GROUND EFFECT NEGLECTED

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Fig. 8

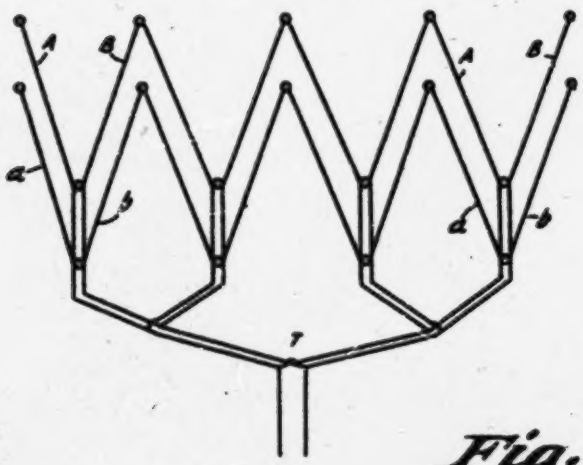


Fig. 10



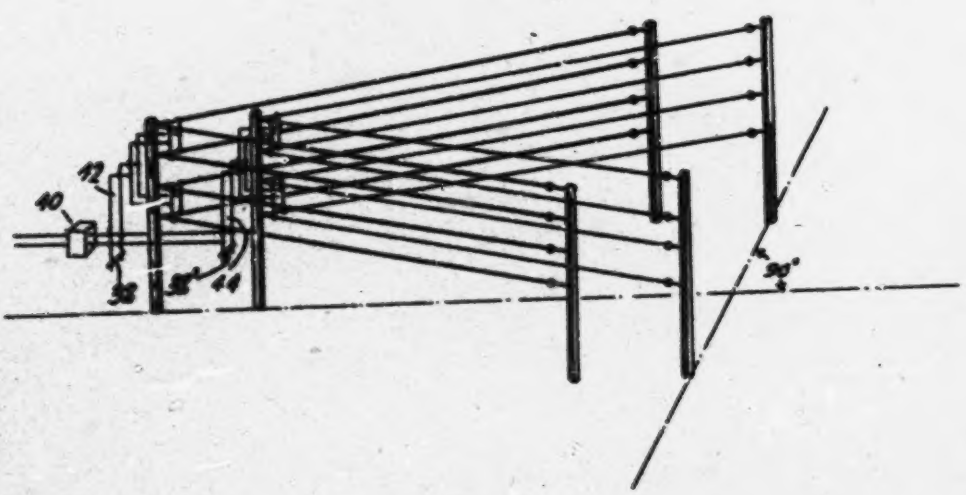
Fig. 10a



Fig. 9



Fig. 11



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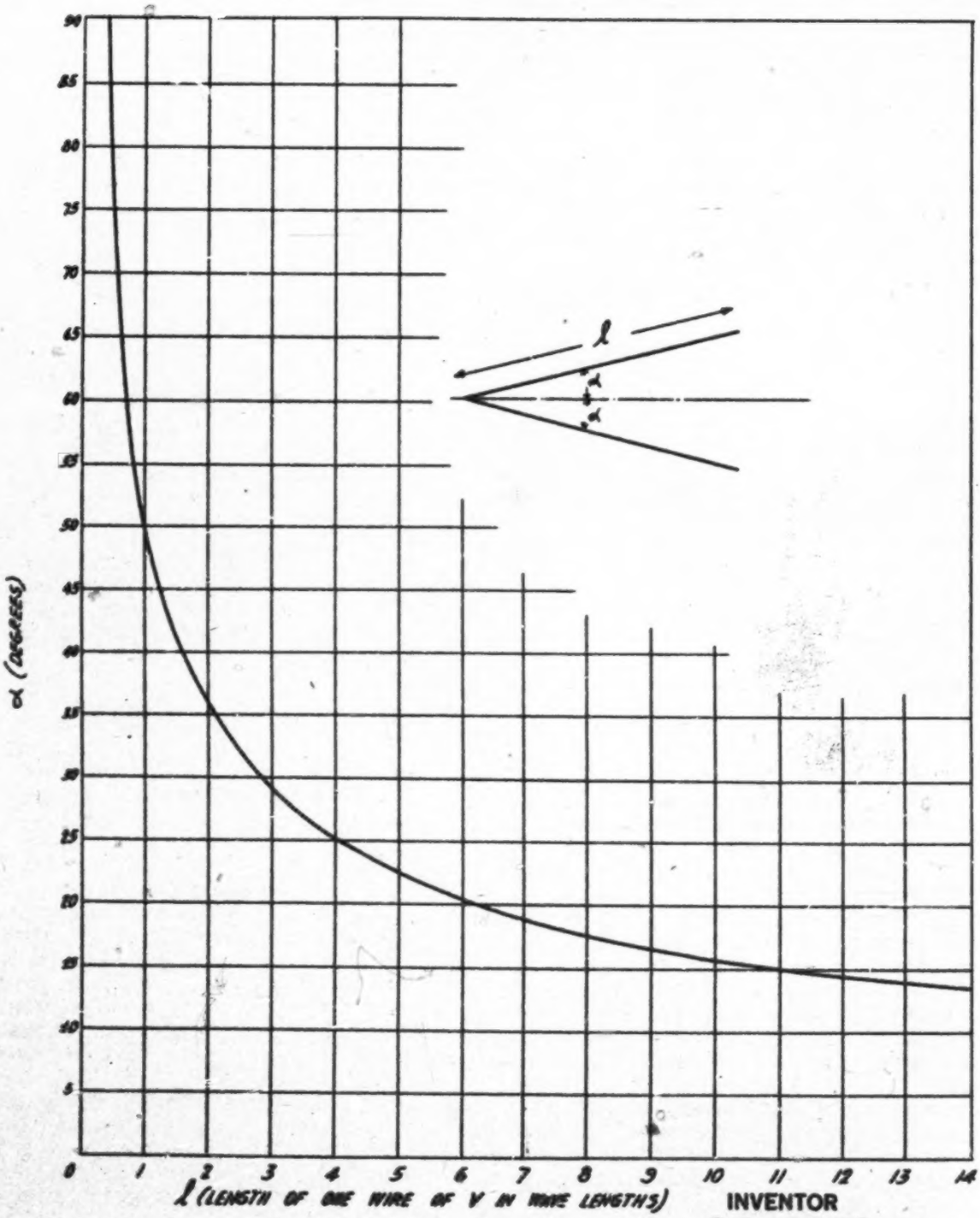
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Fig. 12



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Patented Sept. 18, 1934 1,974,387

UNITED STATES PATENT OFFICE

1,974,387

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Application June 11, 1930, Serial No. 460,467

41 Claims. (Cl. 250—33)

This invention relates to directive antenna systems, and has for its primary object to provide a simplified and highly efficient antenna system utilizing standing wave phenomena.

It is known that when a wire having a length greater than the operating wave length is excited in such manner that standing waves are produced thereon, radiation will occur principally in the direction of symmetrical cones having their apices at the center of the wire. Such is the case with a wire having a length equal to a plurality of one-half wave lengths at the operating frequency. The radiation pattern produced in such instance appears, in cross section, in the form of symmetrical cones about the wire. The present invention, which makes use of these phenomena, in its most simple aspect employs a pair of open-ended wires energized in phase opposition to have standing waves throughout the length of the wires, the wires having such angular relation with respect to each other as to obtain a highly directional, efficient and simple antenna system. It is proposed to place these wires at an angle with respect to each other so that principal radiation takes place along the bisector of the angle. This angle, in general, corresponds to the angle of the principal cone of radiation of one of the conductors.

Another object of the invention is to disclose the angle for the best directional propagation for open-ended wires of any finite length, preferably longer than the operating wave length, having standing waves thereon and arranged in the manner proposed.

Since a pair of wires of the type above described having standing waves of opposite and instantaneous polarity thereon which are angularly disposed with respect to each other, radiate equally well in two directions, i. e., towards the diverging ends of the wires and towards the converging ends of the wires, such an arrangement is bidirectional.

A further object of the present invention therefore is to provide a unidirectional arrangement. This may preferably be accomplished by placing a similar parallel pair of wires an odd number of quarter wave lengths away from the wires forming the antenna proper in a direction taken along the bisector of the angle formed by the wires. The second pair of wires may be left unenergized or floating, or they may be energized in proper phase such that for one direction radiation cancellation occurs, whereas in the other direction there is a strengthening of propagated electromagnetic waves.

A still further object is to concentrate the beam in planes transverse to the plane of the wires. These transverse planes usually include the vertical plane, since the wires are ordinarily disposed in horizontal planes. This may be effected by placing similar arrangements of wires above or below a given arrangement of wires. To increase horizontal directivity, the arrangements of wires may be duplicated side by side.

Other objects and features will appear in the subsequent detailed description referring to the various embodiments of the invention disclosed in the accompanying drawings.

Figure 1*a* illustrates, generally, the principal conical radiational characteristic of a long conductor upon which standing waves are produced,

Figure 1*b* illustrates in cross section, the radiation characteristic of a wire five wave lengths long,

Figures 2*a*, 2*b* and 2*c* indicate various forms of the fundamental unit of the present invention wherein long linear conductors having standing waves thereon are disposed at an angle such that principal radiation occurs along the direction of the bisector of the angle,

Figure 3 indicates the bidirectional characteristic of one of the units shown in any of the Figures 2*a*, 2*b*, or 2*c*,

Figure 4 illustrates an antenna system for concentrating the directional beam radiated from one of the units shown in Figures 2*a*, 2*b*, and 2*c*,

Figure 5 illustrates the arrangement of a plurality of units such as shown in Figure 2 for obtaining unidirectional propagation,

Figures 6 and 7 illustrate, respectively, the power distribution in the horizontal and vertical planes from one antenna system of particular dimensions of the type shown in Figure 5,

Figure 8 illustrates a broadside arrangement of unidirectional units for further increasing the directivity of a propagated beam of electromagnetic waves,

Figure 9 indicates schematically in plan view, an end-on or in line arrangement of units for increasing the directivity of a beam of waves,

Figures 10 and 10*a* indicate diamond shaped arrangements of units for obtaining unidirectional propagation,

Figure 11 illustrates a preferred form of the invention for concentrating a unidirectional beam of energy horizontally and vertically, when the length of wires is of the order of 6 to 12 wave lengths, and,

Figure 12 is a graph showing the relationship between the length of one of a pair of conductors

and half the angle between them for obtaining maximum radiation along the bisector of said angle. As indicated by the sketch of the antenna system in the upper right hand corner of this figure, this relationship holds most strictly when the wires are of equal length.

In general, as shown in Figure 1*a*, there are two principal hollow cones 4, 6 of radiation about a wire such as indicated by the reference character 2, which is long relative to the working wave length. The cones are symmetrical about the wire 2, and the axis of the cones coincides with that of the radiator 2. For a given length of wire measured in wavelengths, the angle α between the axes Y—Y, of each lobe or ear of the cone which appears as such in cross section, and the wire 2 is constant.

More specifically, a cross section of the solid polar diagram of the radiation from a wire, which wire is a number of wave lengths long and has standing waves thereon, contains as many ears per quadrant as there are wave lengths in the wire. Thus, as shown in Figure 1*b*, there are five ears in each quadrant for a wire five wave lengths long, the principal ears or lobes of radiation occurring along the axes Y—Y. As indicated, the instantaneous directions of the field represented by adjacent ears are reversed.

Now, if it is desired to radiate energy principally in the direction of axis X—X of Figures 2*a*, 2*b*, and 2*c*, the conductors, shown in Figure 1, should be turned an angle α relative to the direction X—X; and, in order to increase still further the directional characteristic along the axis X—X, according to the present invention, two wires are used each of which makes an angle α with the axis X—X on opposite sides of the axis in a fashion such that the axis and the pair of wires lie in a single plane. In directions other than along the axis X—X, addition of radiation from the two wires is imperfect, and at certain angles radiation cancellation will occur: Consequently, a pair of wires disposed at the angle α with respect to the X—X axis will have a radiation characteristic in the plane of the pair of wires of the general type shown in Figure 3.

By considering a long wire the equivalent of a very large number of very short, (Hertz) oscillators and by adding up the field components at any point P having a direction angle θ relative to the axis of the wire, where the point P is a great distance from the wire as compared to the length of the wire such that all lines from point P to any point on the wire are essentially parallel, it can be shown that the field strength H is given by the following proportionality for a conductor an odd number of half wave lengths long:

$$H \propto \frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

The letter "n" indicates the number of half wave lengths contained in the wire.

For a wire an even number of half wave lengths long, in similar fashion, the field strength "H" is given by the following proportionality:

$$H \propto \frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

Where n as above indicates the number of half wave lengths on the wire.

The value for which the angle θ in either of the above equations makes the expression a maximum value gives the value for the angle α at which each wire of the V should be disposed relative to the direction X—X of desired wave propagation. Obviously the critical value of θ for either of the above equations may readily be determined; its value for wires up to fourteen wave lengths long is given graphically in Figure 12. For practical purposes the empirical formula

$$\alpha = 50.9\left(\frac{l}{\lambda}\right)^{-0.115} \text{ degrees}$$

is sufficiently accurate where l equals the length of the wire and λ the wave length, both in the same units of measurement. Where a pair of wires of substantially equal length are used to form the V antenna of the present invention, they should be spaced apart at an angle substantially equal to twice the angle α as determined in any of the ways described above.

In order to obtain a bidirectional unit having a characteristic such as shown in Figure 3, as already indicated, any of the arrangements shown in Figures 2*a*, 2*b*, or 2*c* may be utilized. The fundamental unit is shown in Figure 2*a* where a transmission line 10 supplies high frequency energy to a pair of wires A, B forming the angle 2 α with each other. The angle α is the angle made by one of the conductors with the X—X axis along which it is desired that the radiators A, B, propagate energy. The conductors A, B, are joined together at their apex which falls in the axis X—X as shown. The wires may be fed intermediate their ends in a fashion similar to that in which a half wave length oscillator is fed intermediate its ends. If desired, as shown in Figure 2*b*, the radiating wires may be terminated on a transmission line 10 instead of being connected together at the apex as shown in Figure 2*a*.

The arrangement shown in Figure 2*c* is preferred since it facilitates tuning of the antenna unit comprising the pair of wires A, B. The transmission line 10 feeds energy to a U-shaped loop 12, the legs of which are short circuited by an adjustable short circuiting strap 14, representing a voltage nodal point. The ends 16 of the loop 12 supply energy obtained from line 10 to the conductors A, B whereby the conductors are excited in phase opposition. Adjustment of impedance is accomplished along the legs of the loop by suitable adjustable tapping points 18 in order that reflection along transmission line 10 may be reduced.

Use of the loop allows of completion of the tuning of the antenna wires by making the total effective tuning length of each wire of the V or radiating unit substantially equal to an odd number of quarter wave lengths. The effective radiating length is the length of wire included in the V only, since the loop itself is substantially non-radiating and can be made to be any length.

When tuning of the V is properly accomplished by the U-loop, the system presents a pure resistive load to the transmission line. By tapping the transmission line to the legs of the U at a suitable distance from the short circuiting strip, the effective resistance of the antenna system can be made equal to the surge impedance of the line, which is a necessary condition for maximum transmission efficiency.

It should be noted that energy should be fed so as to energize the radiators A, B in phase opposition, otherwise at a distant point P along the axis X—X there would be radiation cancellation instead of addition. It is also to be distinctly understood that the unit, so far described, is not

only useful for radiation purposes in a transmitting arrangement but may be utilized equally as well for reception. That is, the antenna system according to the present invention is equally well suited for any type of radiant action whether it be collection of radiation energy or the transmission thereof.

It is to be further understood that the wires of each unit can be of any desired length provided they are placed at the correct angle for their particular length. For best tuning, the total overall length of both of the wires and the U loop terminating them should be effectively an integral number of half wave lengths, although the portion forming the radiation element can be of any length. The law giving the correct angle for lengths between odd and even number of half wave lengths is not given herein due to its complexity but the empirical formula and the curve of Figure 12 will be found accurate for all practical purposes, whether or not the length of wire dealt with corresponds to an integral number of half wave lengths.

In order to prevent undesired high angle radiation, and in order to concentrate the desired beam in elevation, the scheme shown in Figure 4 may be utilized. In Figure 4, pairs of wires A, B and A', B' are placed in parallel horizontal planes and supported by masts 20 and suitably insulated therefrom by suitable insulators 22. Both pairs of wires or units are fed cophasally from a transmission line 24 through conductors 26, the wires of each pair or unit being fed in opposite phase. In order to increase the elevational concentration of radiated energy, the pair A, B and the pair of wires A', B' are placed apart in horizontal planes by a substantial spacing of preferably not less than one-half wave length. The lower pair should be at least one-half wave length above ground. Bidirectional propagation ensues along the axis X—X but in a much more concentrated form relative to the use of a single unit.

The vertical spacing of the units one above the other need not be made an integral number of half wave lengths. For wires whose lengths approach the order of magnitude from 6 to 10 wave lengths, a spacing greater than one-half wave length is preferred.

In practice, where the height of the antenna is limited by economic considerations and wherein it is desired to make ground absorption as low as possible, a good compromise is a half wave length spacing. For transmission of energy having a wave length of 17 or 18 meters, a good practical antenna may be had wherein the lower wires are about three-quarters of a wave length above ground, and the spacing between wires is one-half wave length. Eighty foot poles or masts may be used to support the wires.

In order to obtain a unidirectional radiation characteristic, pairs of parallel units such as shown in Figures 2a, 2b, and 2c may be spaced apart a distance along the axis X—X, which in effect is the bisector of the angle formed by each pair of wires in each unit. This distance may, in the preferred arrangement, be equal to an odd number of quarter wave lengths.

Such a system combined with means for concentrating the beam in a direction traversing the plane of the wires of each unit is shown in Figure 5. That is, Figure 5 illustrates a system such as shown in Figure 4 duplicated in a direction along the X—X axis whereby, in a horizontal plane, a directional characteristic is obtained such as that shown in Figure 6 and, in a vertical plane a power distribution characteristic such as shown in Figure 7.

The system of Figure 5, comprising the pair of wires A, B paralleled by similar pairs a, b spaced apart along the direction X—X an odd number of quarter wave lengths and, as shown nine-quarters of a wave length behind the apex 28 of wires A, B, is excited so that the wires a, b, have standing current waves thereon 90 degrees ahead in phase of the standing current waves on wires A, B. Consequently, energy will be propagated principally along the axis X—X towards the diverging ends of the radiators. In order to concentrate the beam of energy so radiated, similar pairs of radiators are placed below the pairs A, B and a, b in planes suitably spaced from the first mentioned pairs of radiators to obtain the desired vertical or elevational concentration. The lower pairs of radiators are excited cophasally with respect to the upper pairs through conductors 26, 26' fed by transmission line 24. In order to tune the various units, there are provided U-shaped loops 30, 30' which are short circuited by straps at 32, 32', similar to 14 at Figure 2c and as shown in Figure 11.

By exciting wires a, b 90 degrees lagging relative to radiators A, B, unidirectional propagation may be obtained in an opposite direction, or, towards the converging ends or apices of the units.

If greater concentration of the radiated energy is desired, several systems such as shown in Figure 5, for example, comprising an effective radiating unit A, B and an effective reflecting unit a, b may be placed in broadside with other units, and the several units excited cophasally. Thus, in Figure 8 each of the radiating units A, B shown in plan view is provided with a reflecting unit a, b. By means of branched transmission lines, as shown diagrammatically at T, each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves on the units.

The units may be arranged in end-on fashion or coaxially as shown in Figure 9 where each of the units U is spaced apart in the direction of desired propagation. By making the phase difference between each of the units equal to

$$2\pi\frac{S}{\lambda}$$

where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X—X axis depending upon whether or not the standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression.

Other combinations will readily suggest themselves to those skilled in the art, for example, the units U may be placed diamond shaped fashion such as shown in Figure 10, or, they may be superimposed as shown in Figure 10a, the wires of each unit traversing each other.

In order to obtain greater concentration of the radiated beam of energy in a direction traversing the plane of each unit, the systems may be extended in the fashion shown in Figure 11. Here, the system of Figure 5 has been duplicated in a vertical direction, giving increased concentration of the beam in elevation. Energy is fed to the system through an impedance matching device 40 and thence cophasally to the reflecting units

through a suitable connection 42. Energy is similarly fed to the radiating units through a suitable connection 44. By suitable tuning and by suitable spacing of the radiating pairs of wires and reflecting pairs of wires, unidirectional propagation may be obtained in either direction along the bisector of the angle formed by the wires of each pair.

The spacing of the antenna and reflector, of the system shown in Figure 11 where the wires are 6 to 12 wave lengths long, is made preferably nine-quarters of a wave length. For wires longer than ten waves lengths, the preferred form should have a greater spacing between the antenna and reflector such as two and three-quarters or three and one-quarter wave lengths. For wires on the order of three or four wave lengths long, the reflector spacing from the antenna may be one and one-quarter wave lengths or less. In general, as the lengths of wires in terms of wave lengths increase, the reflector and antenna spacing should be increased.

In each of the systems for reception, the transmission line would simply be coupled to a suitable receiver, the antenna being directed upon a transmitting station.

The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires tilted away from the earth and towards the direction in which the beam of energy is to be propagated.

By the term "plurality of wave lengths", or "plurality of half wave lengths", or "several half wave lengths", it is not intended that the wires so described shall necessarily be an exact or approximate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified.

Having thus described my invention, what I claim is:

1. A directional antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors parallel and similar to said first mentioned pair of conductors and spaced therefrom an odd number of quarter wave lengths measured in a direction along the bisector of the angle of the conductors.

2. A directional transmitting antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths and being open-ended; means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators; and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors, an odd number of quarter wave lengths.

3. A directional antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other in a horizontal plane, each of a length including substantially a plurality of half wave lengths, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

4. A directional transmitting antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths and being open-ended and disposed in a horizontal plane; means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators; and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

5. A directional antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and, another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair in a direction traversing the planes of each pair.

6. A directional antenna comprising a pair of angularly disposed linear conductors said conductors being angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors; and, another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair, in a direction perpendicular to the plane of the pair of conductors a number of half wave lengths.

7. An antenna comprising parallel pairs of angularly disposed conductors, said conductors being angularly disposed with respect to each other, spaced apart along the direction of the bisector of the angle formed by the conductors an odd number of quarter wave lengths, and, similar pairs of conductors in planes parallel to and spaced apart vertically from the planes of the first mentioned pairs of conductors.

8. A transmitting antenna system comprising parallel pairs of angularly disposed conductors, said conductors being angularly disposed with respect to each other, arranged in a horizontal plane having their apices spaced apart along the direction of the bisector of the angle formed by the conductors an odd number of quarter wave lengths, and similar pairs of conductors disposed in a parallel horizontal plane a vertical distance away from said first mentioned plane, equal to one or more half wave lengths.

9. An antenna system comprising a pair of linear conductors, said conductors being angularly disposed with respect to each other, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle substantially equal to the angle for which the field strength at a distant point lying in the direction of the bisector is a maximum, said field strength being proportional to

$$\frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

where n is the number of half wave lengths contained in each conductor and θ is the half angle between the wires, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.

10. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to the angle for which the field strength at a distant point lying in the direction of the bisector is a maximum, said field strength being proportional to

$$\frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

where n is the number of half wave lengths contained in said conductor and θ is the half angle between the wires, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.

11. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle equal to twice the angle for which the expression

$$\frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

is a maximum, n being the number of half wave lengths contained in each conductor, and, a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

12. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to twice the angle for which the expression

$$\frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

is a maximum, n being the number of half wave lengths contained in each conductor, and a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

13. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle equal to twice the angle for which the expression

$$\frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

is a maximum, n being the number of half wave lengths contained in each conductor, and a similar parallel pair of conductors away from the first mentioned pair in a direction perpendicular to the planes of the pairs.

14. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to twice the angle for which the expression

$$\frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

is a maximum, n being the number of half wave lengths contained in each conductor, and a similar pair of conductors away from the first mentioned pair in a direction perpendicular to the planes of the pairs.

15. An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)^{-0.515}$$

degrees, l being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.

16. An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)^{-0.515}$$

degrees, and, a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors, l being the length of each wire and λ being the operating wave length in like units.

17. An antenna comprising pairs of long conductors, the conductors of each pair disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)^{-0.515}$$

degrees, and the pairs being placed in parallel planes substantially an odd number of half wave lengths apart, l being the length of each wire and λ being the operating wave length in like units.

18. An antenna comprising pairs of relatively long conductors the conductors of each pair being disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)^{-0.515}$$

degrees the apices of each pair being separated along the direction of the bisector of the angle formed by the conductors by an odd number of quarter wave lengths; and, similar pairs of conductors in a substantially parallel plane spaced apart from said first pairs, l being the length of each wire and λ being the operating wave length in like units.

19. An antenna arrangement comprising a pair of diverging linear conductors angularly disposed with respect to each other, another pair of angularly disposed diverging conductors similar to said first mentioned pair and spaced apart from said first pair in a direction along the bisector of the angle of the conductors, both said pairs of angularly disposed conductors being arranged to form opposite angles of a four sided plane figure, the conductors of each pair being excited in phase opposition whereby radiant action occurs principally in the plane of said conductors and along the direction of said bisector.

20. A diamond-shaped antenna arrangement comprising a pair of V-shaped antennæ arranged to form a parallelogram, and means for connecting the apex of each V antenna to high frequency apparatus whereby the legs of each V which lie alongside each other are excited in phase opposition so that radiant action occurs principally in the plane of the V-shaped antennæ and principally in a direction along a line joining the apices of said V-shaped antennæ.

21. An antenna system comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of one-half wave lengths and being open-ended, another similar pair of angularly disposed linear conductors also of a length including a plurality of one-half wave lengths and being open-ended, both of said pairs being so arranged that the open ends of one pair point in a substantially opposite direction with respect to the open ends of the other pair and the acute angles formed by said pairs face one another, and means for exciting the radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

22. A directional transmitting antenna arrangement comprising a pair of V-shaped antennæ arranged to form a parallelogram, and means for exciting the radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators whereby radiant action occurs principally in the plane of said radiators and principally along a line joining the apices of said V-shaped antennæ.

23. A directional antenna arrangement comprising a pair of open-ended V-shaped antennæ arranged in a horizontal plane such that the open ends of each pair point in opposite directions with respect to the other pair, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the V-shaped antennæ and principally in a direction corresponding to the line joining the apices of said V-shaped antennæ.

24. A directional antenna arrangement comprising a pair of open-ended V-shaped antennæ arranged such that the acute angle formed by the individual conductors of each pair of antennæ face each other and the open ends of each pair point in different directions, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the V-shaped antennæ and principally in a direction corresponding to a line joining the apices of said V-shaped antennæ.

25. A directional antenna arrangement comprising a pair of V-shaped antennæ arranged in such manner that the acute angle formed by the individual conductors of each pair face each other, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the radiators and principally in a direction corresponding to a line joining the apices of said V-shaped antennæ.

26. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other and placed in a plane at an angle to the horizontal, said plane extending in the desired direction of transmission, each conductor being of a length including substantially a plurality of one-half wave lengths, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of one-quarter wave lengths.

27. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of one-half wave lengths and being open-ended, and disposed in a plane at an angle from the horizontal, said plane extending in the desired direction of transmission, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of one-quarter wave lengths.

28. A directional transmitting antenna comprising a plurality of pairs of linear conductors, the conductors of each pair being angularly disposed with respect to each other, each conductor being of a length including substantially a plurality of one-half wave lengths and being open-ended, said plurality of pairs being disposed in a horizontal plane along the bisector of the angle of the conductors, means for exciting the two radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators of each pair, and means for feeding the successive pairs of radiators so that the currents in the successive radiators of each pair differ in phase by an angle $2\pi S/\lambda$ where S is the spacing along the bisector and λ the wave length.

29. A directional transmitting antenna comprising a plurality of pairs of linear conductors, the conductors of each pair being angularly disposed with respect to each other, each conductor being of a length including substantially a plurality of one-half wave lengths and being open-ended, said plurality of pairs being disposed in a plane at an angle from the horizontal, said plane extending in the desired direction of transmission, means for exciting the two radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators of each pair, and means for feeding the successive pairs of radiators so that the currents in the successive radiators of each pair differ in phase by an angle $2\pi S/\lambda$ where S is the spacing and λ the wave length.

30. A broadside directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, another pair of angu-

larly disposed linear conductors arranged adjacent and in the same plane with said first pair so that said two pairs are side by side and have their acute angles opening in the same direction, and means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisectors of the angles formed by the conductors of each pair for effecting beam concentration.

31. A broadside directional antenna comprising a pair of linear conductors angularly disposed with respect to each other in a horizontal plane, another pair of angularly disposed linear conductors arranged adjacent and in the same plane with said pair so that said two pairs are side by side and have their acute angles opening in the same direction, said pairs being arranged to be excited in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon.

32. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths and being open-ended, a transmission line, a pair of vertical connections extending from said pair of conductors to said transmission line, and means in circuit with said transmission line for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors, another pair of conductors substantially similar and parallel to said first mentioned pair and spaced therefrom in a direction along the bisector of the angle of the conductors, and a pair of vertical connections in circuit with said last pair of conductors, and joining said last pair with said transmission line.

33. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths and being open-ended, a transmission line, a pair of vertical connections extending from said pair of conductors to said transmission line, and means in circuit with said transmission line for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors, another pair of conductors substantially similar and parallel to said first mentioned pair and spaced therefrom in a direction along the bisector of the angle of the conductors, and a pair of vertical connections in circuit with said last pair of conductors, said two pairs of vertical connections being joined together by a pair of horizontal conductors.

34. An antenna arrangement comprising a pair of conductors each of a length including several half wave lengths at the operating frequency, said conductors being angularly disposed at an acute angle with respect to each other, each conductor making the same angle with, but lying on opposite sides of a line representing the desired direction of radiant action, and a U-shaped metallic circuit having legs substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together.

35. An antenna arrangement comprising a pair of conductors each of a length including several half wave lengths at the operating frequency, said conductors being angularly disposed with respect to each other, each conductor making the same angle with, but lying on opposite sides of a line representing the desired direction of radiant action, and a circuit having conductors substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together, and means for effectively connecting together for high frequency currents, similarly located points on each of said parallel conductors.

36. An antenna arrangement comprising a pair of conductors each of a length including several half wave lengths at the operating frequency, said conductors being angularly disposed with respect to each other, each conductor making the same angle with, but lying on opposite sides of, a line representing the desired direction of radiant action, a U-shaped circuit having legs substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together, and a transmission line connected to the legs of said U-shaped circuit and to said angularly disposed conductors for energising said conductors in phase opposition.

37. A directional antenna comprising a pair of angularly disposed substantially straight conductors, said conductors being angularly disposed with respect to each other, each conductor being of a length including a plurality of half wave lengths at a desired operating frequency, means for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon whereby radiant action of the system formed by said angularly disposed linear conductors is predominantly along the direction of the bisector of the angle formed by the conductors, another pair of conductors parallel and similar to said first mentioned pair of conductors, and a substantially radiationless transmission line, not less than a quarter wave length long at the desired operating frequency, joining substantially opposite points on said pairs of conductors, the points on each pair being relatively close together.

38. A directional antenna comprising a pair of straight conductors angularly disposed with respect to each other, each conductor being of a length including a plurality of wave lengths at the operating frequency and being electrically open-ended at their most widely separated ends, means for exciting said conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon, and another pair of open-ended conductors similar and parallel to said first mentioned pair of conductors and being spaced therefrom in a direction along the bisector of the angle of the conductors such that radiant action of said pairs of conductors is substantially unidirectional.

39. A directional antenna comprising a pair of straight conductors angularly disposed with respect to each other, each conductor being of a length including a plurality of half wave lengths at the operating frequency, said conductors being electrically open-ended at their most widely separated ends, another pair of open-ended conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors, and a substantially radiationless transmission line connected between points on said pairs of conductors, the points chosen on each pair being relatively close together, said transmission line being not less than a quarter

wave length long at the desired operating frequency.

40. A directional antenna comprising two pairs of conductors, the conductors of each pair being substantially straight and being arranged so as to form substantially a V, each conductor of each of said pairs of conductors being of a length including a plurality of wave lengths at the desired operating frequency, the most remote ends of the conductors of each pair being electrically open-ended, both pairs of conductors lying in the same plane and symmetrically about a line representing a desired direction of radiant action.

41. A directional antenna comprising two pairs of conductors, the conductors of each pair being substantially straight and being arranged so as to form substantially a V, each conductor of each of said pairs of conductors being of a length including a plurality of wave lengths at the desired operating frequency, the most remote ends of the conductors of each pair being electrically open-ended, both pairs of conductors lying in the same plane and symmetrically about a line representing a desired direction of radiant action, and a substantially radiationless transmission line not less than a quarter wave length long connected between similar points on said pairs of conductors, the points taken on each pair of conductors being close together relative to the electrical open ends of said conductors.

PHILIP STAATS CARTER.

PLAINTIFF'S EXHIBIT No. 7

DESCRIPTION OF SAYVILLE ANTENNA NO. 8

The defendant's WMZ-20 antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit A, WMZ-20 Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to San Francisco, California (bearing approximately N 281° E), and Chicago, Illinois (bearing approximately N 278° E), on a wave-frequency of 5990 kilocycles which corresponds to a wave-length of 50.08 meters (164.3 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on the said diagram):

The antenna system comprises two V-type antennae (ACBD and A'C'B'D', respectively), lying in the same horizontal plane 80 feet above the ground surface. The length of each of the four antenna wires AC, BD, A'C', and B'D' is 657 feet. The adjacent ends C, D, of the wires constituting one V antenna are 15 inches apart and are connected through a pair of wires, CI and DJ, respectively, to another pair of wires leading from the points I and J, respectively, to the transmitter. The adjacent ends, C',D', of the wires constituting the other V antenna are 15 inches apart and are connected through a pair of wires C'I'I and D'J'J, respectively, to the said pair of wires leading from the points I and J, respectively, to the transmitter. The wires CI and DJ are vertical. The pair of wires C'I'I and D'J'J comprise

a vertical section C'I' and D'J' and an horizontal section I'I and J'J. The wires CI, C'I'I, and the wire from I to the transmitter are spaced 12" from the wires DJ, D'J'J, and the wire from J to the transmitter, respectively. All of the said wires, as well as the antenna wires, are #6 copper-clad steel wire.

The wires leading from the points I, J to the transmitter are each approximately 800 feet long; the said wires and, therefore, the two wires of each antenna are fed in phase opposition. The vertical wires CI, DJ, C'I', and D'J' are each approximately 42 feet lon and the horizontal wires I'I and J'J are each approximately 123 feet long.

The bearing of the horizontal line bisecting the angle between the wires AC and BD and the angle between the wires A'C' and B'D', taken from the apices toward the open ends, is approximately 282° east of true north.

Connected to the wires leading from the points I, J to the transmitter, at points K and L approximately 12 feet from I and J, are two parallel wires, KM and LN, each approximately 15 feet long, which wires KM and LN are open ended. Similarly, connected to the vertical wires CI and DJ, at points E and F approximately 27 feet from C and D, are two parallel wires EG and FH; the wires EG and FH are closed by the cross-connection GH located approximately 10 feet from the points E, F. Similarly, connected to the vertical wires C'I' and D'J', at points E' and F' approximately 36 feet from C' and D', are two parallel wires E'G' and F'H'; the wires E'G' and F'H' are closed by the cross-connection G'H' located approximately 9 feet from the points E', F'. The wires KM, EG, and E'G' are spaced 12" from the

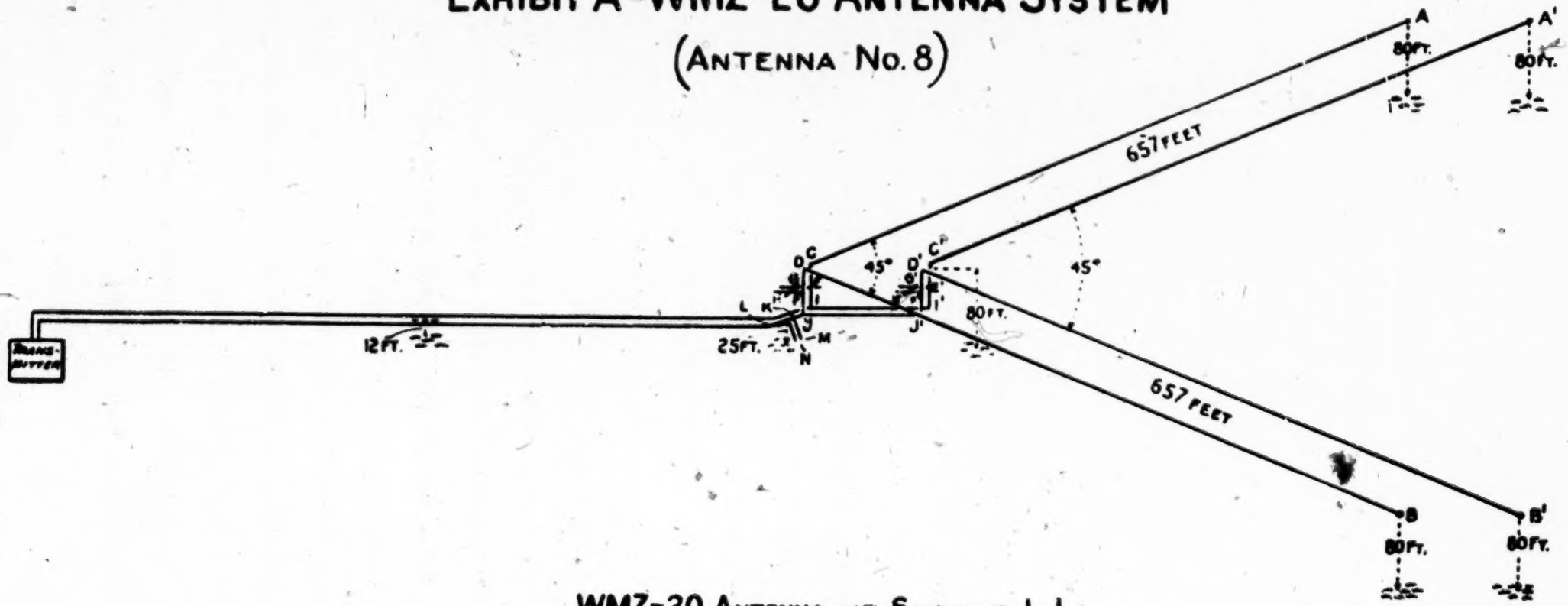
wires LN, FH, and F'H', respectively. All of the said wires, as well as the cross-connections GH and G'H', are #6 copper-clad steel wire.

The antenna wires, together with the wires from the transmitter to the antennae, the positions of the three pairs of parallel wires and of the two cross-connections, and the length of the parallel wires KM, LN, were so adjusted when the antenna system was installed, that an approximate impedance match was provided at each of the pairs of points KL, EF, and E'F', whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from each of said pairs of points is reduced. Waves are reflected intentionally between the points LJ, and MN, via KL, as well as between the antenna ends, AB, and GH, via EF, and the antenna ends, A'B', and G'H', via E'F'. The reflected waves are reduced as above stated on the wires EI, FJ, E'I'I, and F'J'J and on the wires leading from points KL to the transmitter. The antenna system is directive and the angle between the wires AC and BD and between A'C' and B'D' is 45°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave length, are tabulated in Exhibit G.

EXHIBIT A - WMZ-20 ANTENNA SYSTEM

(ANTENNA No. 8)



WMZ-20 ANTENNA AT SAYVILLE, L.I.

5990 KILOCYCLES FREQUENCY OR

WAVELENGTH - λ = 50.08 METERS (164.3 FEET)

PLAINTIFF'S EXHIBIT No. 8

DESCRIPTION OF SAYVILLE ANTENNA NO. 1C

The defendant's WKT antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit B, WKT Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to San Francisco, California (bearing approximately N 281° E), on a wave-frequency of 16,370 kilocycles, which corresponds to a wavelength of 18.326 meters (60.13 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on the said diagram):

The antenna system comprises two V-type antennae (ACBD and A'C'B'D', respectively), lying in the same horizontal plane 80 feet above the ground surface. The length of each of the four antenna wires AC, BD, A'C', and B'D' is 431 feet. The adjacent ends, C, D, of the two wires constituting one V antenna are connected by wires, each 1.58 feet long, to the upper ends E, F, of two vertical copper tubes each 15.03 feet long, having an outside diameter of one inch, and spaced 9.5 inches apart, center to center; the lower ends G, H, of these tubes are connected direct to the junction points I, J. The distance from the points C, D, to the points, I, J, is 16.58 feet. Another pair of parallel wires 12" apart leads from the points I, J, to the transmitter. The adjacent ends C',D' of the wires constituting

the other V antenna are connected by wires, each 1.58 feet long, to the upper ends E', F', of two vertical copper tubes each 15.03 feet long, having an outside diameter of one inch, and spaced 7.25 inches apart, center to center; the lower ends G',H', of these tubes are connected direct to the points I',J', and thence by horizontal wires, spaced 12" apart and each 135 feet long, to the junction points I, J. The distance from the points C',D', to the points I',J', is 16.58 feet. The points C, D and C',D' on the antennae are separated, respectively, 12 and 10 inches. All of the wires, including the antenna wires, are #6 copper-clad steel wire.

The wires leading from the points I,J to the transmitter are each approximately 221 feet long; the said wires and, therefore, the two wires of each antenna, are fed in phase opposition.

The bearing of the horizontal line bisecting the angle between the wires AC and BD and the angle between the wires A'C' and B'D', taken from the apices toward the open ends of the V's, is approximately 282° East of true North.

Connected to the wires leading from the points I,J to the transmitter, at points K and L 4.5 feet from I and J, are two parallel wires, KM and LN, each 5.5 feet long and spaced 12" apart, which wires KM and LN are open ended.

The antenna wires, together with the conductors leading from the transmitter to the antennae, the position and length of the pair of wires KM and LN, and the length, diameter, and position of the copper tubes were so selected and adjusted, when the antenna system was installed, that an

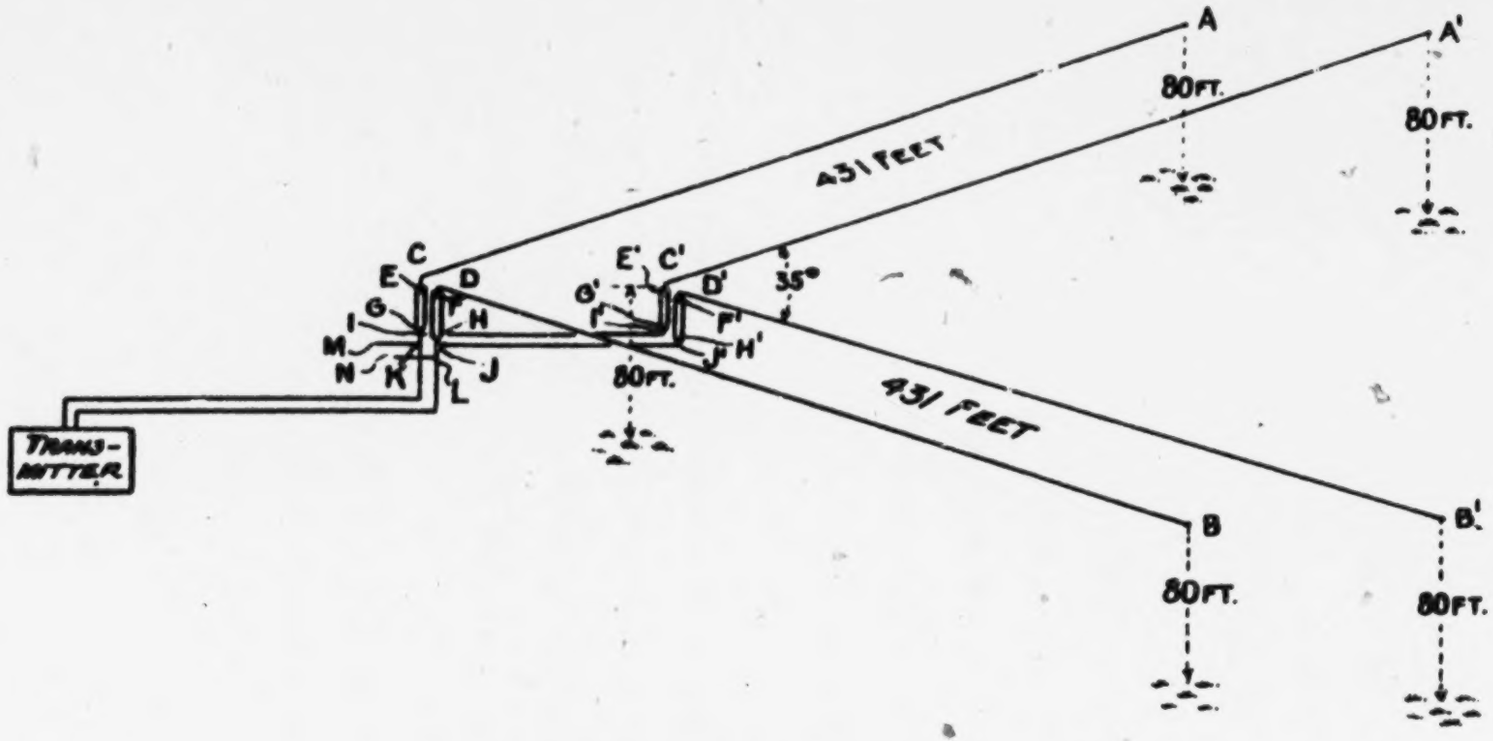
approximate impedance match was provided at each of the pairs of points KL, GH and G'H', whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from KL and from G'H' is reduced. Waves are reflected intentionally between the points I,J, and M,N, via K,L, as well as from the antenna ends A,B, toward the points E,F, and from the antenna ends A',B', toward the points E',F'. The reflected waves are reduced as above stated on the wires G'I'I, and H'J'J and on the wires leading from points K,L, to the transmitter. The antenna system is directive, and the angle between the wires AC and BD and between A'C' and B'D' is 35°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave lengths, are tabulated in Exhibit G.

Other antennae Nos. 4, 5, and 6 were, at the time of the commencement of this suit, constructed and adjusted like No. 10 described in the foregoing, except as to the specific differences shown by the tabulation in Exhibit G.

EXHIBIT B-WKT ANTENNA SYSTEM

(ANTENNA NO. 10)



WKT ANTENNA AT SAYVILLE, L.I.

16,370 KILOCYCLES FREQUENCY OR

WAVELENGTH -λ- 18.326 METERS (60.13 FEET)

PLAINTIFF'S EXHIBIT No. 9

DESCRIPTION OF SAYVILLE ANTENNA NO. 1

The defendant's WIU antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit C, WIU Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to San Francisco, California (bearing approximately N 281° E) on a wave-frequency of 10,170 kilocycles, which corresponds to a wavelength of 29.5 meters (96.79 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on the said diagram):

The antenna system comprises two V-type antennae (ACBD and A'C'B'D', respectively), lying in the same horizontal plane 80 feet above the ground surface. The length of each of the four antenna wires AC, BD, A'C', and B'D', is 601 feet. The adjacent ends, C, D, of the two wires constituting one V antenna are connected by wires, each 1.58 feet long, to the upper ends, E,F, of two vertical copper tubes each 24.2 feet long, having an outside diameter of one inch, and spaced 7.5 inches apart, center to center; the lower ends G,H, of these tubes are connected by wires seven inches long to the junction points I, J. The distance from points C, D, to points I, J, is 26.33 feet. Another pair of parallel wires 12" apart leads from the points I, J, to the transmitter. The adjacent ends, C', D', of the wires constituting the other V antenna are connected by wires, each 2.08 feet long, to the upper ends, E', F', of two vertical

copper tubes each 24.2 feet long, having an outside diameter of one inch, and spaced 5.5 inches apart, center to center; the lower ends, G',H', of these tubes are connected direct to the points I',J', and thence by horizontal wires, spaced 12" apart and each 72.67 feet long, to the junction points I, J. The distance from points C',D', to points I',H', is 26.33 feet. The points C, D and C',D' on the antennae are separated, respectively, 11 and 15 inches. All of the wires, including the antenna wires, are #6 copper-clad steel wire.

The wires leading from the points I, J to the transmitter are each approximately 1089 feet long; the said wires and, therefore, the two wires of each antenna, are fed in phase opposition.

The bearing of the horizontal line bisecting the angle between the wires AC and BD and the angle between the wires A'C' and B'D', taken from the open ends of the V's toward their apices, is approximately 282° East of true North.

Connected to the wires leading from the points I,J, to the transmitter, at points K and L 55.58 feet from I and J, are two parallel wires, KM and LN, each 8.42 feet long and spaced 12" apart, which wires KM and LN are open ended.

The antenna wires, together with the conductors leading from the transmitter to the antennae, the position and length of the pair of wires KM and LN, and the length, diameter and position of the copper tubes were so selected and adjusted, when the antenna system was installed, that an approximate impedance match was provided at each of the pairs of points

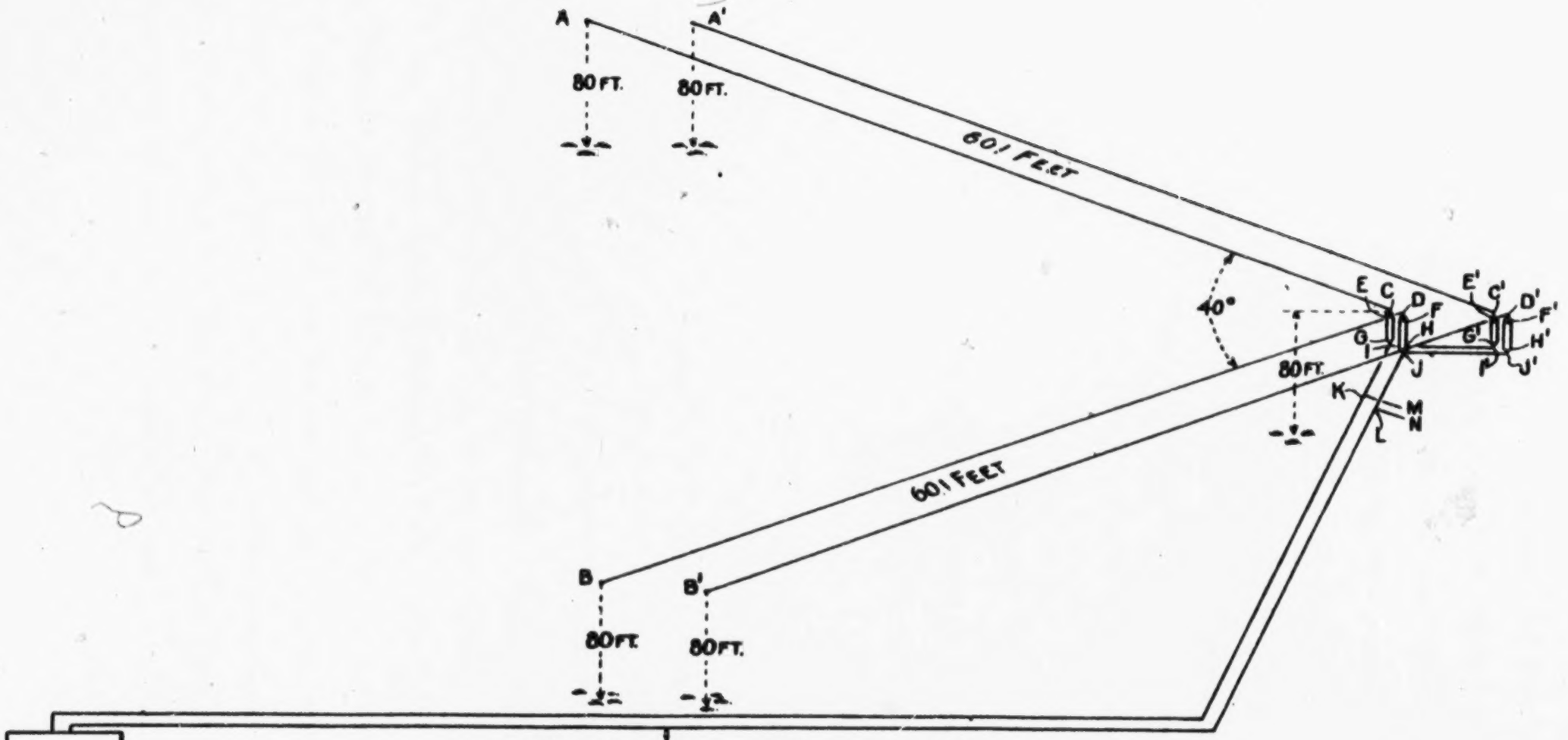
KL, GH and G'H', whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from each of said pairs of points is reduced. Waves are reflected intentionally between the points I, J, and M, N, via K, L, as well as from the antenna ends A, B, toward the points E, F, and from the antenna ends A',B', toward the points E', F'. The reflected waves are reduced as above stated on the wires GI, HJ, G'I'I, and H'J'J and on the wires leading from points K,L, to the transmitter. The antenna system is directive, and the angle between the wires AC and BD and between A'C' and B'D' is 40°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave lengths, are tabulated in Exhibit G.

Antenna #9 was, at the time of the commencement of this suit, constructed and adjusted like No. 1, described in the foregoing, except as to the specific differences shown by the tabulation in Exhibit G.

EXHIBIT C-WIU ANTENNA SYSTEM

(ANTENNA NO. 1)



WIU ANTENNA AT SAYVILLE, L.I.

10,170 KILOCYCLES FREQUENCY OR

WAVELENGTH - λ - 29.50 METERS (96.79 FEET)

704

PLAINTIFF'S EXHIBIT No. 10

DESCRIPTION OF SAYVILLE ANTENNA NO. 2

The defendant's WML antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit D, WML Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to the European cities of Copenhagen (bearing approximately N 43° E), Vienna (bearing approximately N 50° E), Budapest (bearing approximately N 50° E), and Vatican City (bearing approximately N 58° E) on a wave-frequency of 14,740 kilocycles, which corresponds to a wavelength of 20.35 meters (66.77 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on the said diagram):

The radiating system comprises a single V-type antenna, ACBD, lying in a horizontal plane 80 feet above the ground surface. The length of each of the two antenna wires, AC and BD, is 517 feet. The adjacent ends, C, D, of the two wires constituting the V antenna are connected by vertical wires, each 67 feet long and spaced 12" apart, to the points I, J, and thence by a horizontal continuation of these wires, similarly spaced and each approximately 752 feet long, to the transmitter. The points C and D on the antenna are spaced 9" apart. All of the wires, including the antenna wires, are #6 copper-clad steel wire.

The said wires leading from the transmitter to the points C, D, and, therefore, the two wires of the antenna, are fed in phase opposition.

The bearing of the horizontal line bisecting the angle between the wires AC and BD, taken from the open ends toward the apex, is approximately 50° East of true North.

Connected to the wires leading from the points C,D to the transmitter, at points K and L 30 feet from I and J, are two parallel wires, KM and LN, each 7.17 feet long and spaced 12" apart. The wires KM and LN are closed by the cross-connection MN, located 7.17 feet from K, L.

The antenna wires, together with the wires from the transmitter to the antenna, the position and length of the pair of wires KM and LN, and the position of the cross-connection MN, were so adjusted, when the antenna system was installed, that an approximate impedance match was provided at the pair of points KL, whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from said pair of points is reduced. Waves are reflected intentionally between the antenna ends A,B, and the points MN, via KL. The antenna system is directive, and the angle between the wires AC and BD is 35°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave lengths, are tabulated in Exhibit G.

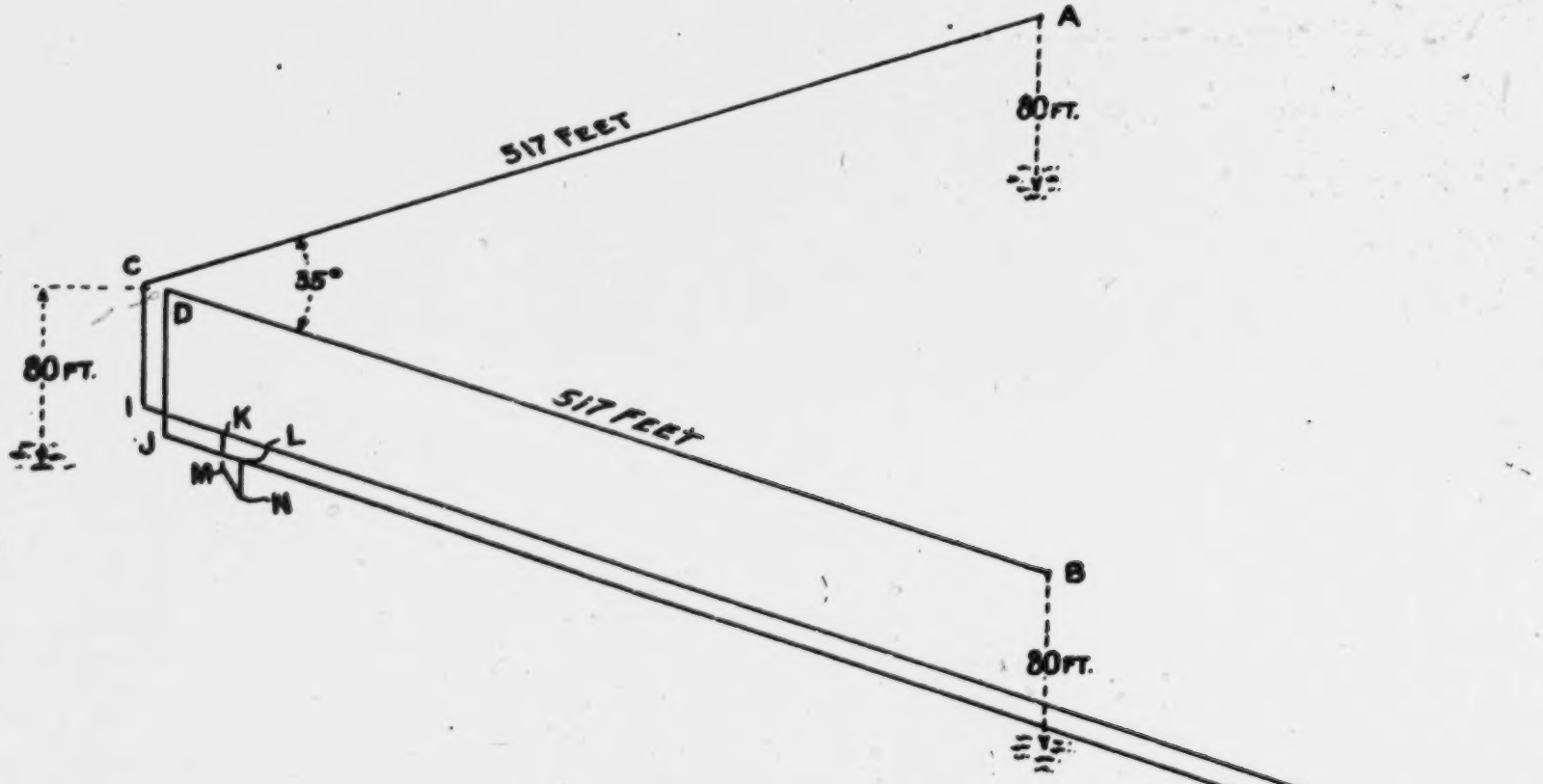
Antenna #3 was, at the time of the commencement of this suit, constructed and adjusted like No. 2 described in

the foregoing, except as to specific differences which so far as now known are shown by the tabulation in Exhibit G.

Antennae Nos. 2 and 3 were rebuilt after the commencement of this suit, and when rebuilt were constructed and adjusted like antenna #2 above described, except as to the specific differences shown by the tabulation in Exhibit G.

EXHIBIT D - WML ANTENNA SYSTEM
(ANTENNA NO. 2)

522 708



WML ANTENNA AT SAYVILLE, L.I.

14,740 KILOCYCLES FREQUENCY OR

WAVELENGTH - λ - 20.35 METERS (66.77 FEET)

PLAINTIFF'S EXHIBIT No. 11

DESCRIPTION OF SAYVILLE ANTENNA #11

The defendant's WKS antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit E, WKS Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to the European cities of Copenhagen (bearing approximately N 43° E), Vienna (bearing approximately N 50° E), Budapest (bearing approximately N 50° E), and Vatican City (bearing approximately N 58° E) on a wave-frequency of 16,285 kilocycles, which corresponds to a wavelength of 18.42 meters (60.44 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on the said diagram):

The radiating system comprises a single V-type antenna, ACBD, lying in a horizontal plane 80 feet above the ground surface. The length of each of the two antenna wires, AC and BD, is 465 feet. The adjacent ends, C, D, of the two wires constituting the V antenna are connected by wires, each 2.1 feet long, to the upper ends E, F, of two vertical copper tubes each 15.08 feet long, having an outside diameter of 13/16 of an inch, and spaced 6 inches apart, center to center; the lower ends G, H, of these tubes are connected by wires, 1.5 feet long, to the points I,J. The distance from the points C, D, to the points I, J, is 18.75 feet. Another pair of parallel wires, 12" apart and each approximately 111 feet long, leads from the points I,J, to the transmitter.

The points C and D on the antenna are spaced 9 inches apart. All of the wires, including the antenna wires, are #6 copper-clad steel wire.

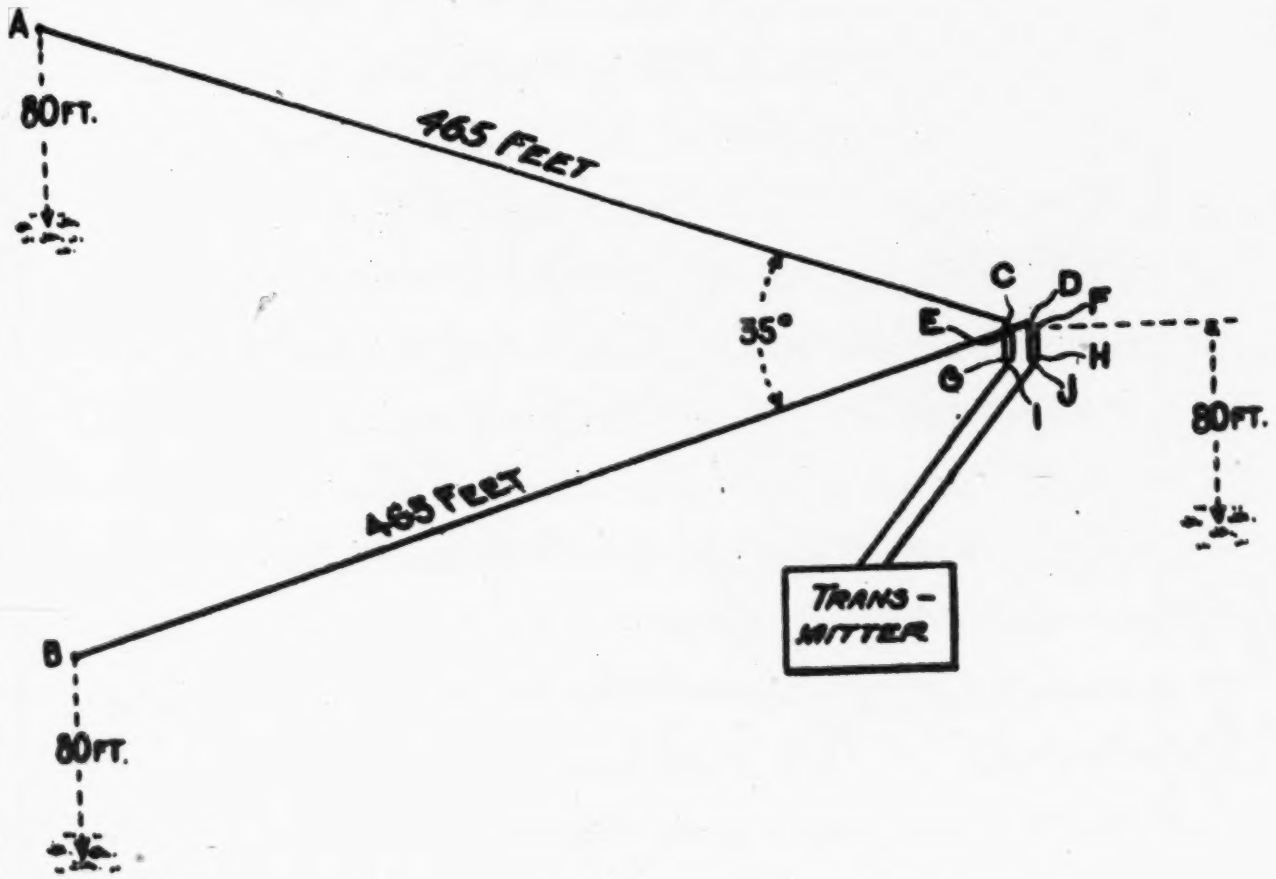
The said wires leading from the transmitter to the points C, D, and, therefore, the two wires of the antenna, are fed in phase opposition.

The bearing of the horizontal line bisecting the angle between the wires AC and BD, taken from the apex toward the open ends, is approximately 48° East of true North.

The antenna wires, together with the conductors from the transmitter to the antenna, and the length, diameter and position of the copper tubes, were so selected and adjusted, when the antenna system was installed, that an approximate impedance match was provided at the pair of points GH, whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from said pair of points is reduced. Waves are reflected intentionally from the antenna ends A,B, toward the points EF. The antenna system is directive, and the angle between the wires AC and BD is 35°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave lengths, are tabulated in Exhibit G.

EXHIBIT E-WKS ANTENNA SYSTEM
(ANTENNA NO.11)



WKS ANTENNA AT SAYVILLE, L.I.

16,285 KILOCYCLES FREQUENCY OR

WAVELENGTH = λ = 18.42 METERS (60.44 FEET)

PLAINTIFF'S EXHIBIT No. 12

DESCRIPTION OF SAYVILLE ANTENNA NO. 7

The defendant's WJE antenna system at Sayville, Long Island, New York, had, at the time of the commencement of this suit, substantially the arrangement and dimensions shown in the drawing hereto annexed and marked "Exhibit F, WJE Antenna System". This antenna system, at the time above stated, was being utilized by defendant in the transmission of commercial messages for pay to Buenos Aires (bearing approximately N 167° E), Camaguay (bearing approximately N 182° E), Seattle (bearing approximately N 298° E), and New Orleans (bearing approximately N 237° E), on a wave-frequency of 10,830 kilocycles, which corresponds to a wavelength of 27.7 meters (90.88 feet). Following is a description of this antenna system as it existed at the time above stated (the reference characters being shown on said diagram):

The antenna system comprises two V-type antennae (ACBD and A'C'B'D', respectively), lying in the same horizontal plane 80 feet above the ground surface. The length of each of the four antenna wires AC, BD, A'C', and B'D' is 867 feet. The adjacent ends, C, D, of the two wires constituting one V antenna are connected by wires, each 45 feet long, to the upper ends E, F, of two vertical copper tubes each 22.76 feet long, having an outside diameter of one inch, and spaced 7 inches apart, center to center; the lower ends G, H, of these tubes are connected direct to the junction points I, J. The distance from the points C, D, to the points, I, J, is 67.75 feet. Another pair of parallel

wires 12" apart leads from the points I, J, to the transmitter. The adjacent ends C',D' of the wires constituting the other V antenna are connected by wires, each 45 feet long, to the upper ends E',F', of two vertical copper tubes each 22.76 feet long, having an outside diameter of one inch, and spaced 7 inches apart, center to center; the lower ends G',H', of these tubes are connected direct to the points I',J', and thence by horizontal wires, spaced 12" apart and each 68.33 feet long, to the junction points I, J. The distance from the points C',D', to the points I',J', is 67.75 feet. Each of the points C, D and C',D' on the antennae are separated 10 inches. All of the wires, including the antenna wires, are #6 copper-clad steel wire.

The wires leading from the points I,J to the transmitter are each approximately 151 feet long; the said wires and, therefore, the two wires of each antenna, are fed in phase opposition.

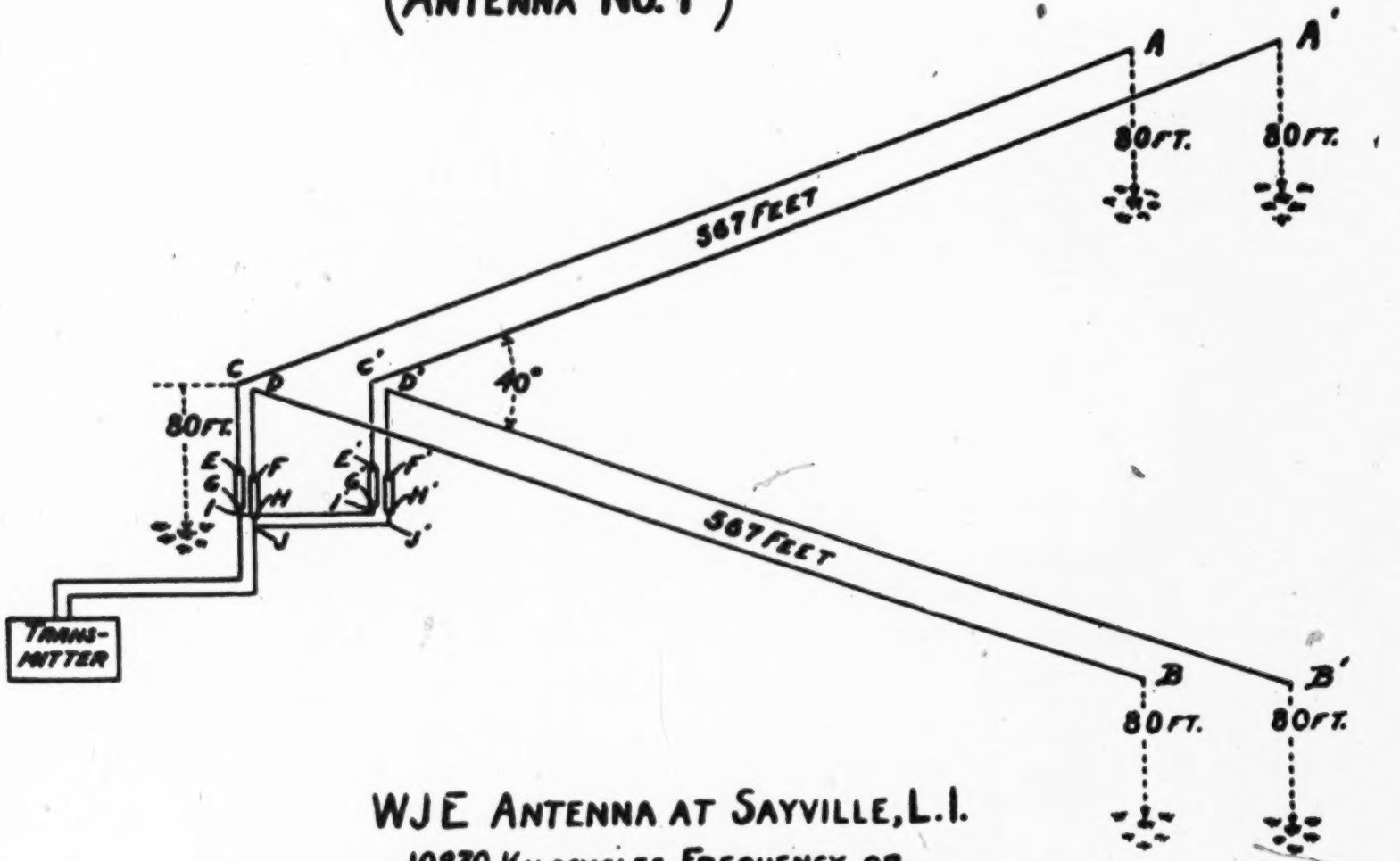
The bearing of the horizontal line bisecting the angle between the wires AC and BD and the angle between the wires A'C' and B'D', taken from the apices toward the open ends of the V's, is approximately 167° East of true North.

The antenna wires, together with the conductors leading from the transmitter to the antennae, and the length, diameter, and position of the copper tubes were so selected and adjusted, when the antenna system was installed, that an approximate impedance match was provided at each of the pairs

of points GH and G'H', whereby energy is efficiently transferred across each of said pairs of points and reflection of waves toward the transmitter from G'H' is reduced. Waves are reflected intentionally from the antenna ends A,B, toward the points E,F, and from the antenna ends A',B', toward the points E',F'. The reflected waves are reduced as above stated on the wires G'I'I, and H'J'J. The antenna system is directive, and the angle between the wires AC and BD and between A'C' and B'D' is 40°.

The dimensional data set forth in the foregoing description, together with alternative statements of certain dimensions in terms of wave lengths, are tabulated in Exhibit C.

EXHIBIT F - WJE ANTENNA SYSTEM
(ANTENNA NO. 7)



WJE ANTENNA AT SAYVILLE, L.I.

10830 KILOCYCLES FREQUENCY OR

WAVELENGTH - λ - 27.7 METERS (90.88 FEET)

4/41

716

529

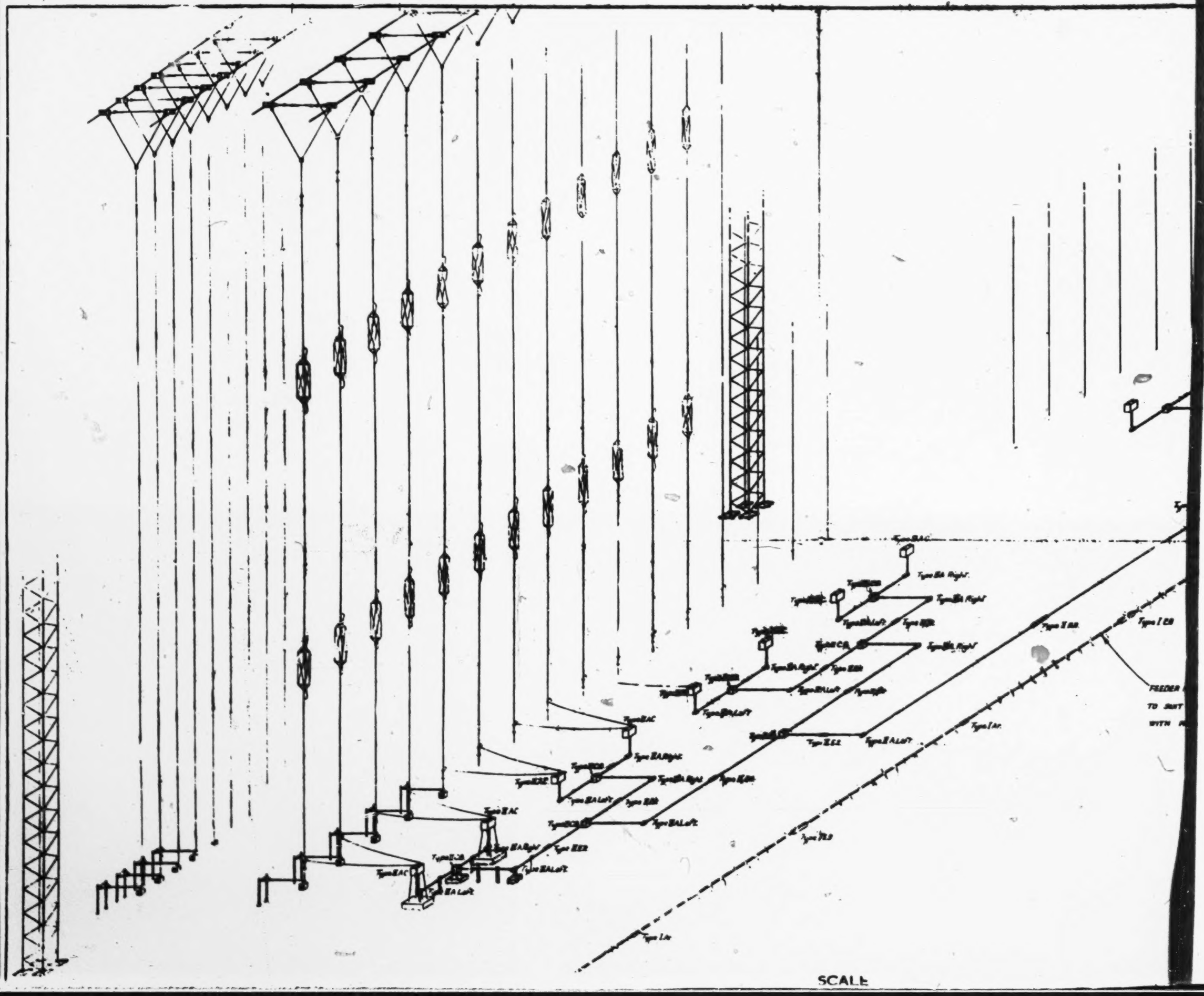
EXHIBIT G — Tabulation of Dimensional Data for V-Antennas at Sayville

Sheet I

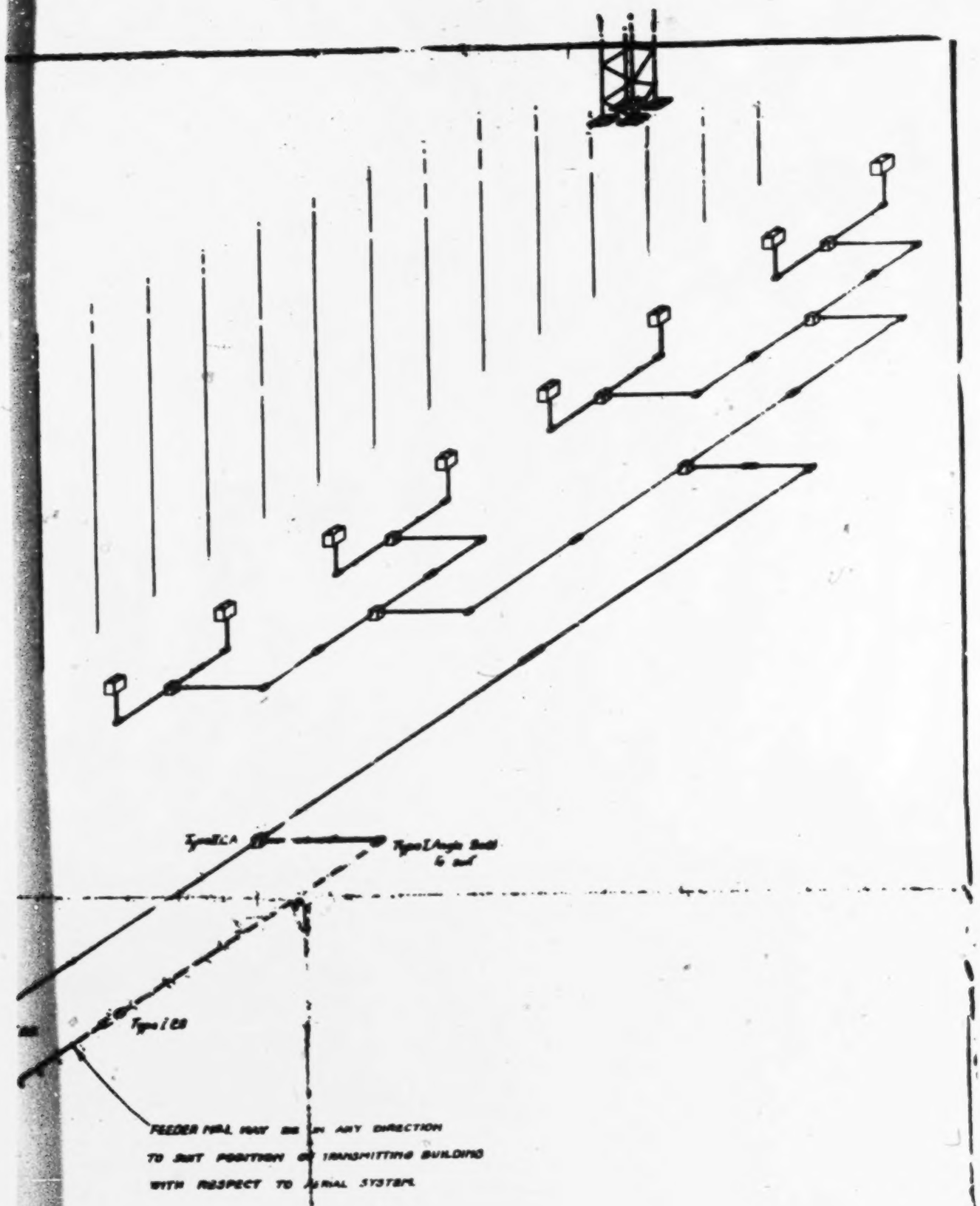
Antenna No:	1	2 Original	2 Rebuilt	3 Original	3 Rebuilt	4	5	6	7	8	9	10	11
Call Letters	WIU	WML	WKB	WKR	WIX	WJH	WIW	WMY	WJE	WMZ	WKI	WKT	WKS
Frequency	10170 Kc	14740 KC	14695 KC	17140 KC	10820 KC	13018 KC.	10810 KC	20880 KC	10830 KC	5990 KC	14710 KC	16370 KC	16285 KC
Wavelength	29.50m	20.35 m.	20.42 m.	17.50 m.	27.73 m	23.05 m	27.75 m	14.30 m	27.70m	50.08 m	20.39 m.	18.326 m.	18.42 m.
Wavelength	96.78 ft	66.77 ft.	66.99 ft.	57.43 ft	90.98 ft.	75.63 ft.	91.04 ft.	46.92 ft.	90.88 ft.	164.3 ft.	66.90 ft.	60.13 ft.	60.44 ft.
Single or Double V	Double	Single	Single	Single	Single	Double	Double	Double	Double	Double	Double	Double	Single
Communicates with: (and bearing E. of N.)	San Francisco (281.28°)	Copenhagen (43.36°)	San Francisco (281.28°)	Budapest (49.62°)	New Orleans (236.59°)	Copenhagen (43.36°)	Copenhagen (43.36°)	Buenos Aires (167.44°)	Buenos Aires (167.44°)	San Francisco (281.28°)	San Francisco (281.28°)	San Francisco (281.28°)	Copenhagen (43.36°)
		Vienna (49.74°)				Vienna (49.74°)	Vienna (49.74°)		Camaguey (182.47°)	Chicago (278.46°)			Vienna (49.74°)
		Budapest (49.62°)				Budapest (49.62°)	Budapest (49.62°)		Seattle (297.58°)				Budapest (49.62°)
		Vatican City (57.9°)				Vatican City (57.9°)	Vatican City (57.9°)		New Orleans (236.59°)				Vatican City (57.9°)
Directivity E. of N.	281.95°	48.75°	280.82°	49.62°	238°	48.25°	48.25°	167.5°	167.5°	281.95°	281.95°	281.95°	48.25°
Length of horizontal wire:	1089 ft	752 ft.	478 ft.	Unknown	1265 ft	516 ft.	837 ft	600 ft	151 ft.	800 ft.	624 ft.	221 ft.	111 ft.
Angle of V Apex:	40°	35°	40°	35.73°	43°	35°	40°	35°	40°	45°	35°	35°	35°
Length each V wire	6.21 wl.	7.74 wl.	8.14 wl.	7.89 wl.	4.85 wl.	7.69 wl.	6.21 wl.	7.07 wl.	6.24 wl.	4 wl.	7.70 wl.	7.17 wl.	7.69 wl.
do.	601 ft.	517 ft	545 ft.	441.5 ft.	441.5 ft	582 ft	565 ft.	360 ft.	567 ft.	657 ft.	515 ft.	431 ft.	465 ft.
Height above ground	0.83 wl.	1.2 wl.	1.19 wl.	1.39 wl.	0.88 wl.	1.06 wl.	0.9 wl.	1.49 wl.	0.88 wl.	0.49 wl.	1.2 wl.	1.33 wl.	1.32 wl.
do.	80 ft.	80 ft.	80 ft.	80 ft.	80 ft.	80 ft.	80 ft	70 ft.	80 ft.	80 ft.	80 ft.	80 ft.	80 ft.
Separation of V's	3/4 wl.	—	—	—	—	1 1/4 wl.	3/4 wl.	1 3/4 wl.	3/4 wl.	3/4 wl.	1 3/4 wl.	2 1/4 wl.	—
do.	72.67 ft	—	—	—	—	94.67 ft.	68.25 ft.	82 ft.	68.33 ft.	123 ft.	117 ft.	135 ft.	—

EXHIBIT G Tabulation of Dimensional Data for V-Antennas at Sayville, con. Sheet II

Antenna No:	1	2 Original	2 Rebuilt	3 Original	3 Rebuilt	4	5	6	7	8	9	10	11
Length C to E, D to F	26.33 ft.	67 ft	43.83 ft	Unknown	5.42 ft.	20.42 ft	25.25 ft	15.42 ft.	67.75 ft	42 ft	19.83 ft	16.58 ft.	18.75 ft.
Length C' to E', D' to F'	26.33 ft	—	—	—	—	20.58 ft.	25.23 ft.	14.42 ft	67.75 ft	42 ft.	19.5 ft.	16.58 ft	—
Length C to E, D to F	1.58 ft	—	—	—	—	1.5 ft.	2.5 ft.	2.25 ft.	45 ft.	—	2.67 ft.	1.58 ft.	2.1 ft.
Length C' to E', D' to F'	2.08 ft	—	—	—	—	1.67 ft.	2.5 ft.	2.67 ft.	45 ft.	—	2.75 ft.	1.58 ft.	—
Length E to G, F to H	24.2 ft.	—	—	—	—	18.91 ft.	22.72 ft.	11.73 ft.	22.76 ft.	—	16.72 ft.	15.03 ft.	15.88 ft.
Length E' to G', F' to H'	24.2 ft	—	—	—	—	18.91 ft	22.72 ft.	11.73 ft.	22.76 ft.	—	16.72 ft.	15.03 ft.	—
Length G to I, H to J	7 in.	—	—	—	—	0	0	1.42 ft.	0	—	5 in.	0	1.5 ft.
Length G' to I', H' to J'	0	—	—	—	—	0	0	0	0	—	0	0	—
O.D. Copper Tubes	1 in.	—	—	—	—	1 in.	1 in.	1 in.	1 in.	—	1 in.	1 in.	11/16 in.
Spacing of Cu-Fe (C to C)	7.5 in.	—	—	—	—	6 in.	7.5 in.	4.25 in.	7 in.	—	8 in.	9.5 in.	6 in.
Spacing of C'-F' (C' to C')	5.5 in.	—	—	—	—	6.5 in.	7 in.	5 in.	7 in.	—	8.5 in.	7.25 in.	—
Length I to K, J to L	55.58 ft.	30 ft.	101.08 ft.	Unknown	107.33 ft.	80.25 ft.	51.08 ft.	72.58 ft.	—	12 ft.	108 ft.	4.5 ft.	—
Length M to N, L to K	8.42 ft.	7.17 ft.	8.33 ft.	Unknown	10.25 ft.	5.58 ft.	8.25 ft.	4.25 ft.	—	15 ft.	7.42 ft.	5.3 ft.	—
Ant open or closed	Open	Closed	Open	Unknown	Closed	Open	Open	Open	—	Open	Open	Open	—
Spacing C to D	11 in.	9 in.	9 in.	Unknown	12 in.	13 in.	10 in.	14 in.	10 in.	15 in.	10 in.	12 in.	9 in.
Spacing C' to D'	15 in.	—	—	—	—	12 in.	10 in.	10 in.	10 in.	15 in.	16 in.	10 in.	—
Length C to E, D to F	—	—	—	—	—	—	—	—	—	27 ft.	—	—	—
Length E to G, F to H	—	—	—	—	—	—	—	—	—	10 ft.	—	—	—
Gate open or closed	—	—	—	—	—	—	—	—	—	closed	—	—	—
Length C' to E', D' to F'	—	—	—	—	—	—	—	—	—	25 ft.	—	—	—
Length E' to G', F' to H'	—	—	—	—	—	—	—	—	—	9 ft	—	—	—
Gate open or closed	—	—	—	—	—	—	—	—	—	closed	—	—	—


SCALE

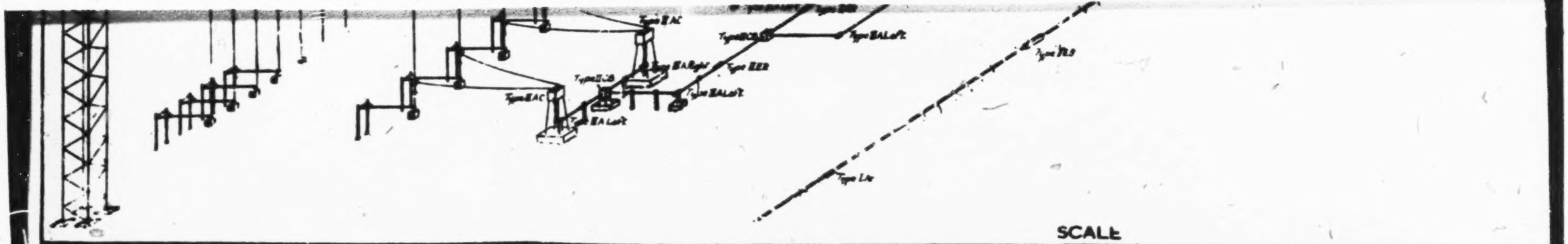
PLAINTIFF'S EXHIBIT No. 14



SUPPORTS FOR FEEDER BOXES DEMA 32384/1
" " " " " 32424
FEEDERLINE SUPPORTS. 32617/1
DETAILS OF FEEDERS. 32298/1

[redacted]

SECT No	DATE	ALTERATIONS OR CORRECTIONS	INITIAL
/1	6-10-36	Reflector wires & inductances added	[illegible]



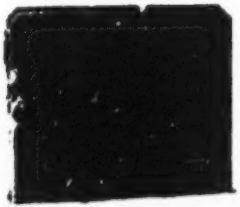
SCALE

BEAM STATIONS

SCHEMATIC DIAGRAM OF FEEDER CIRCUIT & AERIAL. FOR WAVERANCE 22·5 – 40 METRES.

WITH RESPECT TO AERIAL SYSTEM.

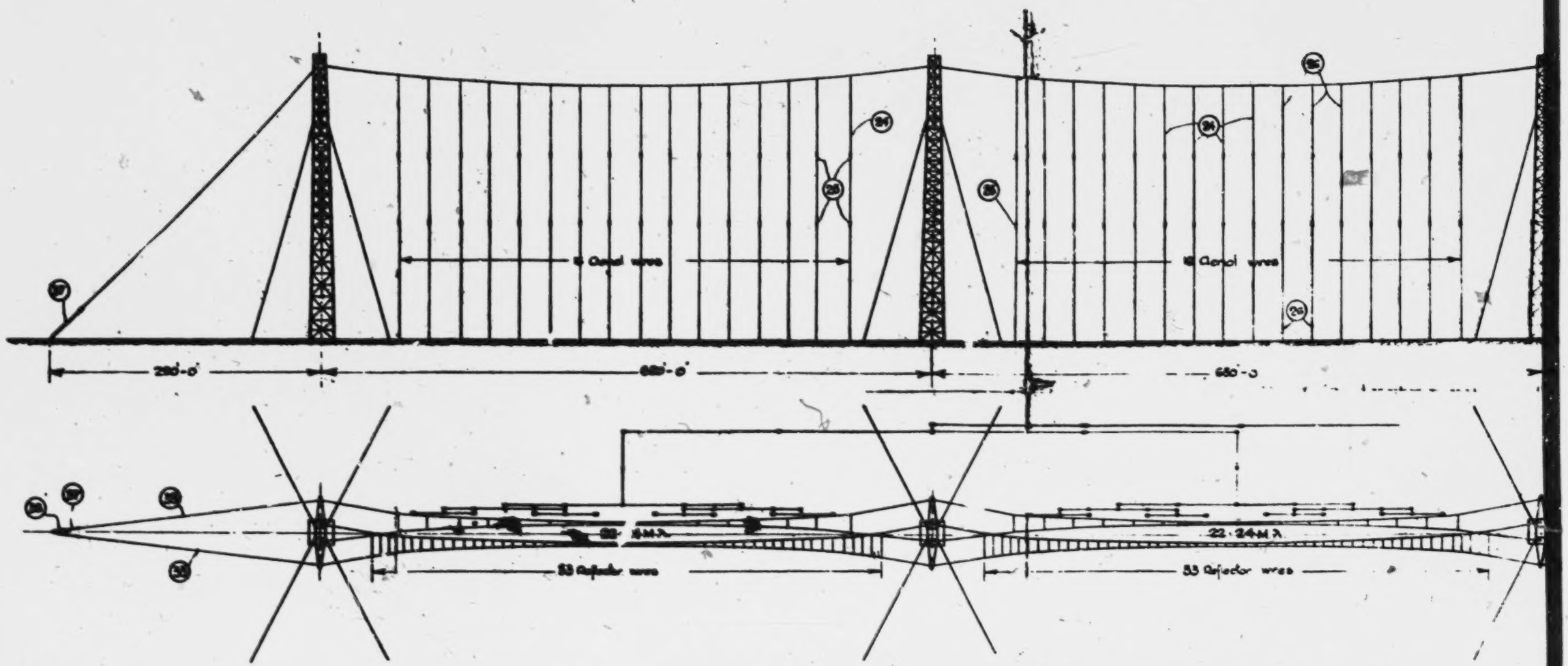
SUPPORTS FOR FEEDER BOXES DRG No 32284/1
" " " " " 32424
FEEDERLINE SUPPORTS. 32617/1
DETAILS OF FEEDERS. 32284/1



DRG No	DATE	ALTERATIONS OR CORRECTIONS	INITIAL
/1	6-10-26	Reflector wires & inductances added	F JR

DRAWN BY: C.L.
TRACED BY: C.S.R.
CHECKED BY:

MARCONI'S WIRELESS TELEGRAPH CO LTD
LONDON.
No 32251/1



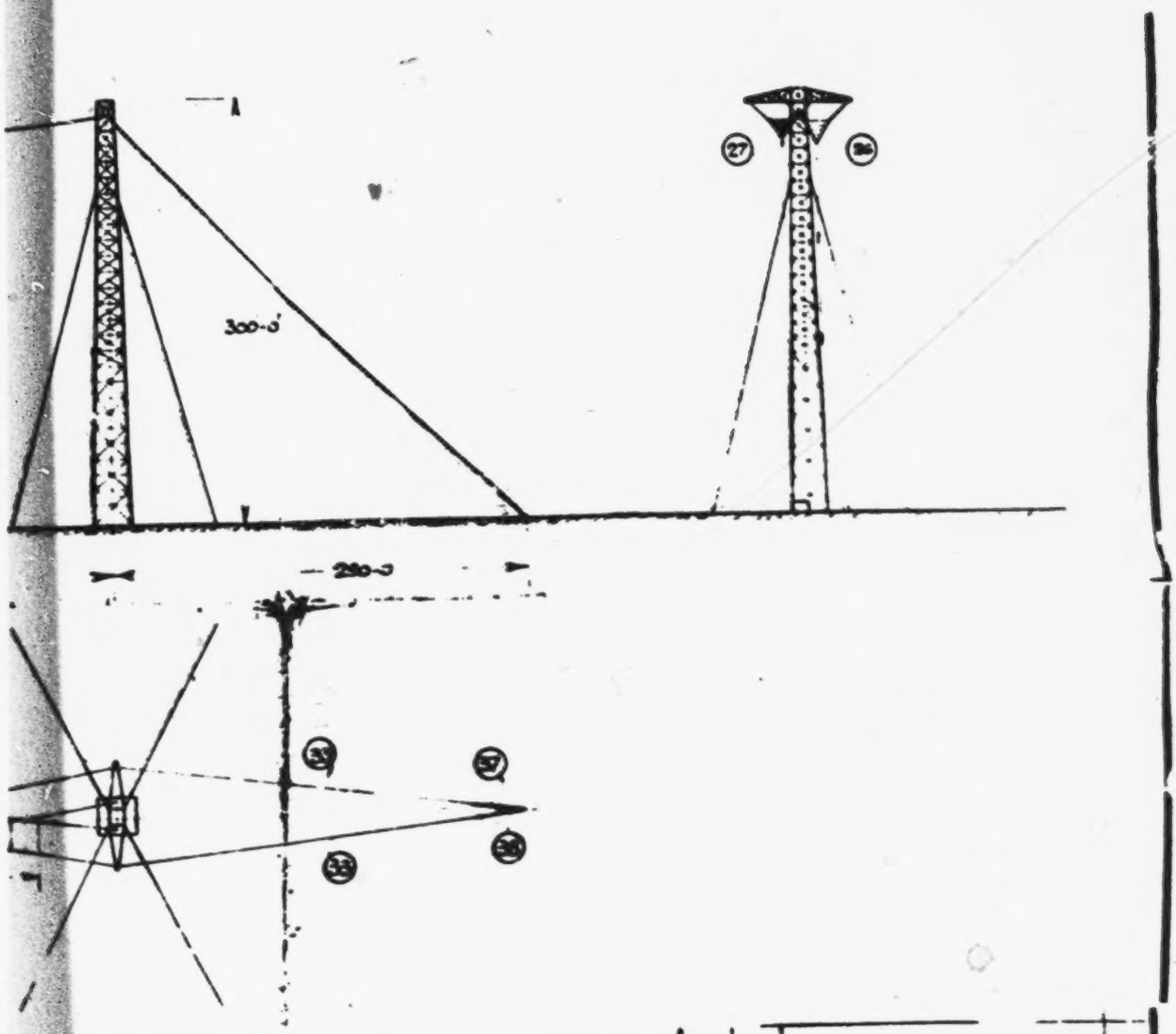
SCALE

ROCKY POINT NEW YORK	GENERAL ARRANGEMENT OF AERIAL & REFLECTOR SYSTEM BEAM TRANSMITTER

1720 720

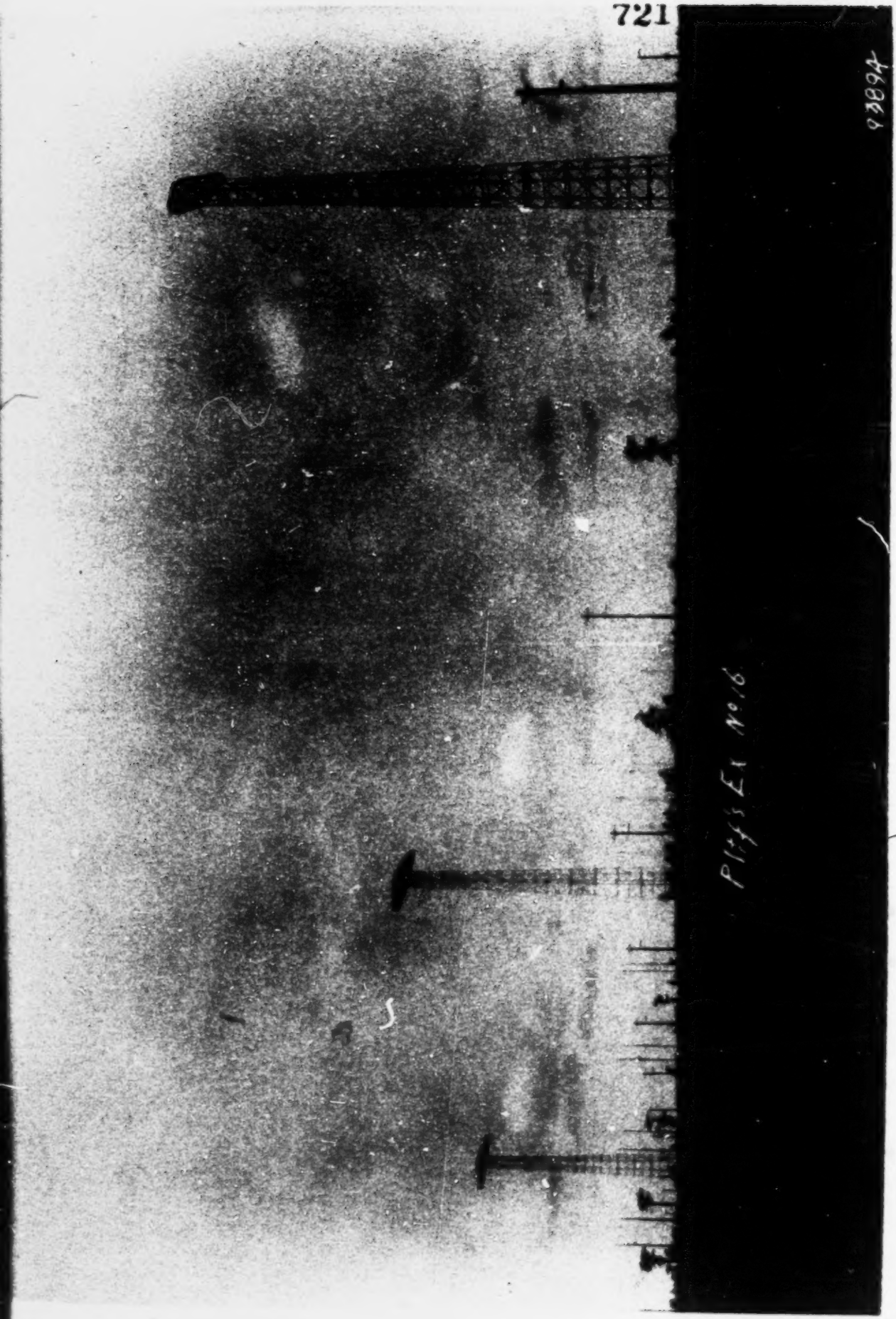
PLAINTIFF'S EXHIBIT No. 15

NO. 15



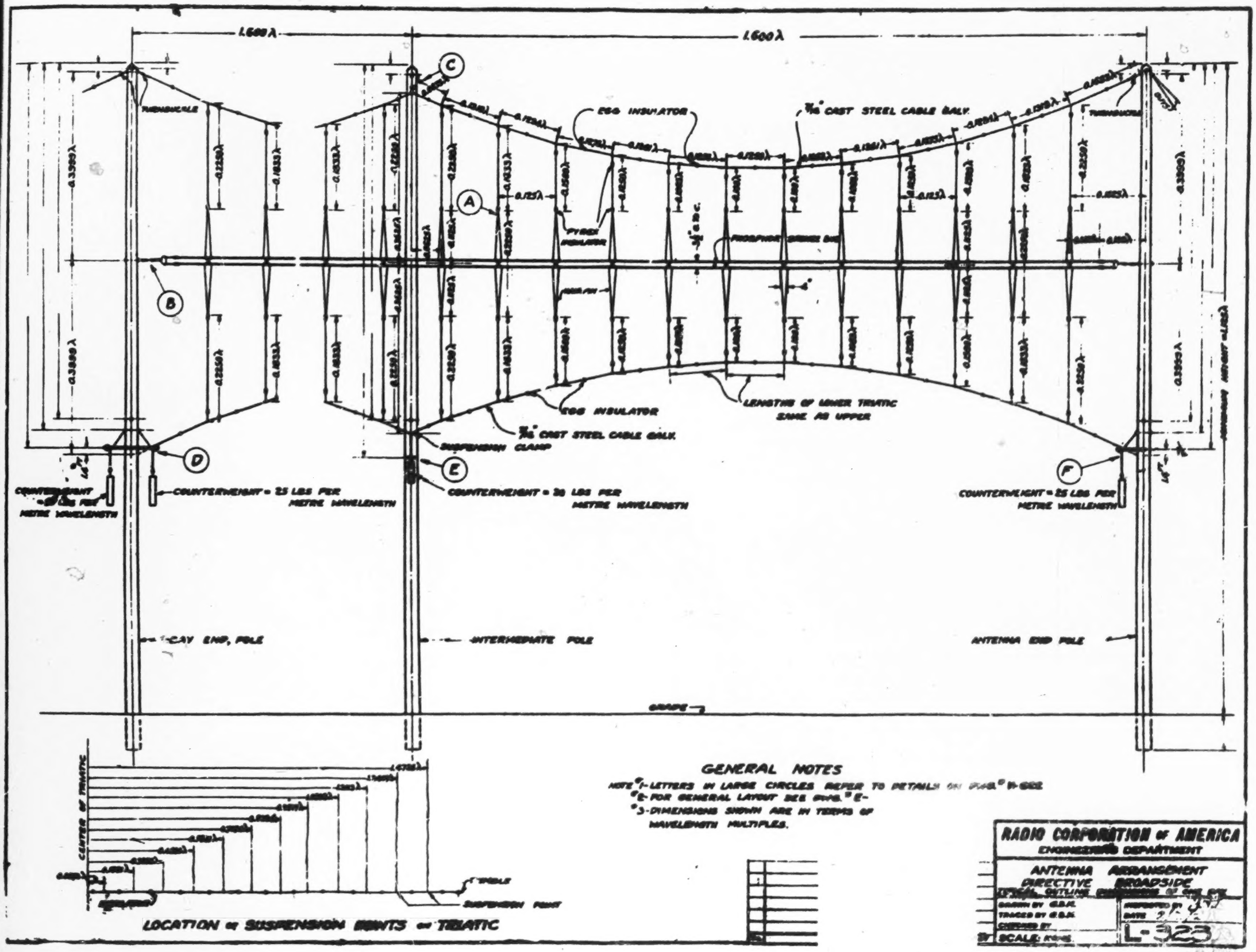
STEM

DRAWN BY	MARCONI'S WIRELESS TELEGRAPH Co LTD LONDON.
TRACED BY	
CHECKED BY	No 35567


721
PLATE No 16
9 3894


PIff's Ex No 17
83900

PLAINTIFF'S EXHIBIT No. 18



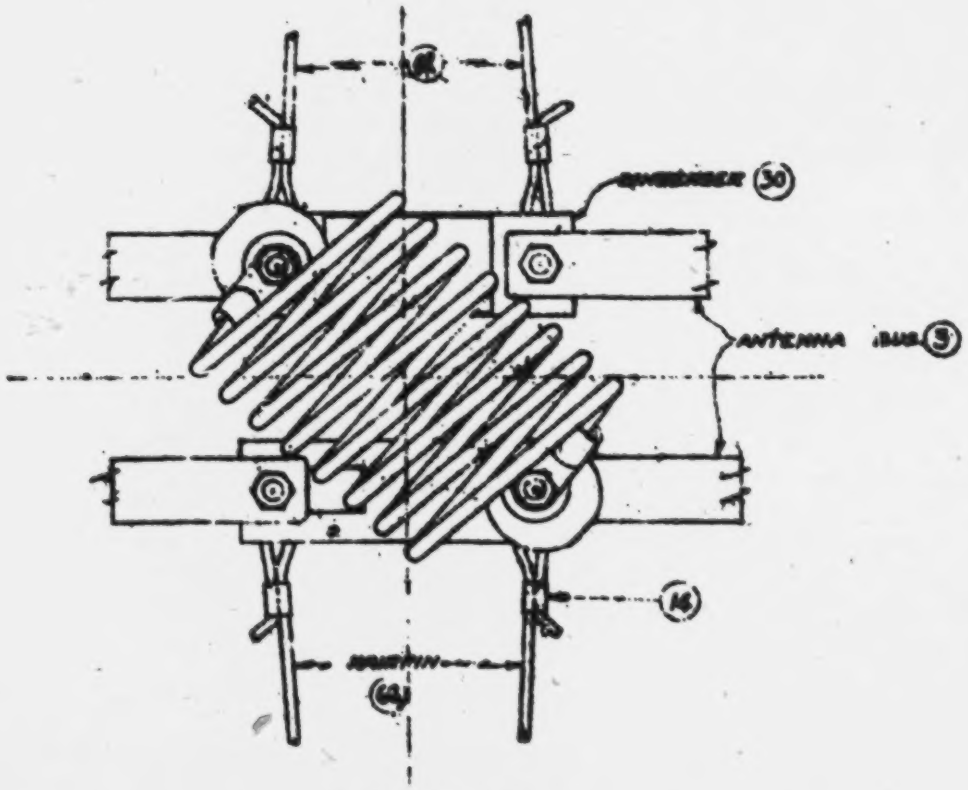
GENERAL NOTES

NOTE 1- LETTERS IN LARGE CIRCLES REFER TO DETAILS ON DWG. D-602
2- FOR GENERAL LAYOUT SEE DWG. E-
3- DIMENSIONS SHOWN ARE IN TERMS OF WAVELENGTH MULTIPLES.

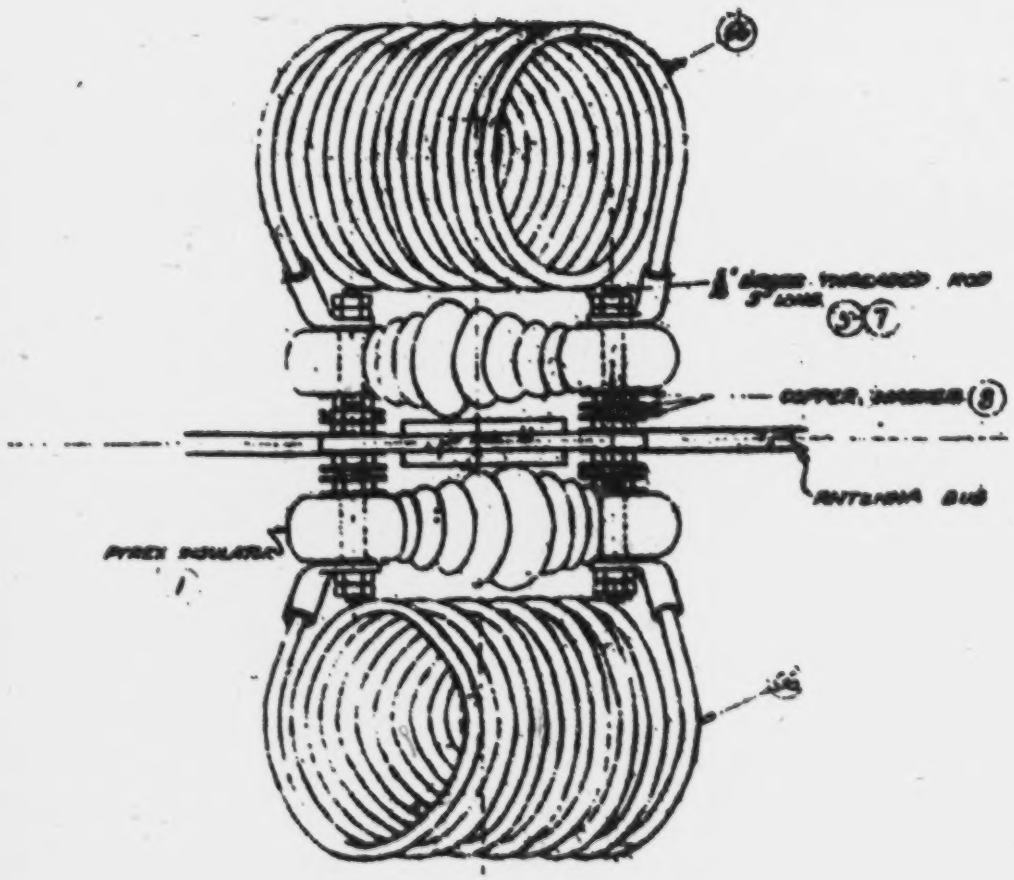
RADIO CORPORATION of AMERICA
ENGINEERING DEPARTMENT

ANTENNA ARRANGEMENT
DIRECTIVE BROADSIDE
SPECIAL OUTLINE CHARACTERISTICS OF THIS SYS.

DRAWN BY G.B.A.
TRACED BY G.B.A.
CHECKED BY
SCALE: NONE
REPORTED BY
DATE 7-1-
L-323

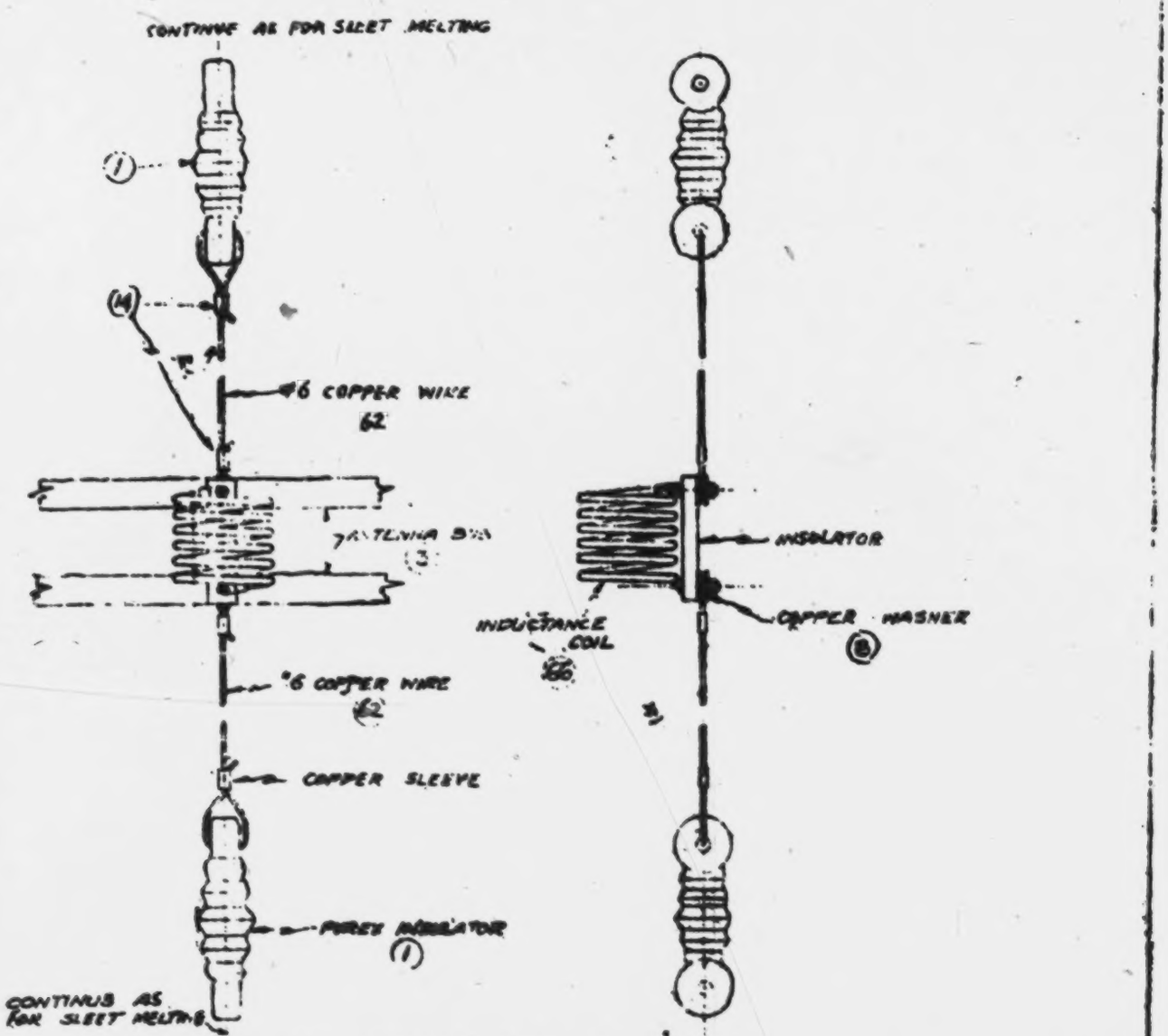


ELEVATION



PLAN

PLAINTIFF'S EXHIBIT No. 19



ASSEMBLY FOR NON-SLEET MELTING

4

SCALE:- 4"=1"

GENERAL NOTES

NOTE:- 1- LETTERS IN LARGE CIRCLES REFER TO DETAILS.
2- NUMBERS IN SMALL CIRCLES REFER TO ITEMS ON BILL OF MATERIAL FOR WAVELENGTH USED.

RADIO CORPORATION OF AMERICA
ENGINEERING DEPARTMENT

ASSEMBLY DETAILS
BROADSIDE ANTENNA

DRAWN BY [redacted]	INSPECTED BY [redacted]
TRACED BY	APPROVED 1/24/28
CHECKED BY	V-622
SCALE:- AS SHOWN	

PLAINTIFF'S EXHIBIT No. 20

Proceedings of the Institute of Radio Engineers
Volume 19, Number 10 *October, 1931*

DEVELOPMENT OF DIRECTIVE TRANSMITTING ANTENNAS BY R.C.A COMMUNICATIONS, INC.*

By

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(R.C.A. Communications, Inc., Rocky Point, N. Y.)

Summary—Progressive stages in the development of short-wave directive antennas for long-distance communication are outlined. The scope of development described embraces the period from 1923, beginning with experiments on a transmitting wave antenna at Belfast, Maine, to the present commercial directive antennas used in the world-wide short-wave system of R.C.A. Communications, Inc.

Various types of directive antennas are theoretically analyzed and their performances under practical conditions studied. The effects of seasonal variations, heights above ground and polarization are considered. The radiation properties of simple wires and the radiation patterns of various combinations of wires are described in detail.

The economic aspects of these directive antennas as exemplified by the standard antenna models A, B, C, and D are developed.

Introduction

ACTIVE work on the development of directive transmitting antennas was begun by the engineers of the Radio Corporation of America[1] in 1923, at which time it was becoming apparent that wavelengths[2] of less than 200 meters might have important applications in radio communications. The application of these short wavelengths made it possible to deliver given amounts of signal power to distant receiving stations more economically by using directive antennas.

In setting out to develop directive transmitting antennas we had an ideal in performance to strive for represented by the wave antenna developed for long-wave reception by Beverage, Rice, and Kellogg.[3] This antenna, in addition to being very directional, is simple in structure and is substantially aperiodic. A single structure may be used for operation over a wide range of wavelength without any tuning adjustments.

Early Wave Antenna Experiments

Due to realization of the great advantages of the wave antenna for reception it was natural to choose it for the first directive transmitting

* Decimal classification: R125. Original manuscript received by the Institute, March 19, 1931. Presented before Sixth Annual Convention of the Institute, June 6, 1931, Chicago, Illinois.

[1] The group of engineers whose work is related in this paper are now in R.C.A. Communications, Inc., a subsidiary of the Radio Corporation of America, under C. H. Taylor, vice president, engineering.

[2] Wavelengths are used in this paper instead of frequency because of the close relation between wavelength and the factors affecting the design and explanation of directive antennas.

[3] "The Wave Antenna" by Beverage, Rice, and Kellogg, *Trans. A.I.E.E.*, 42, 258 et. seq., March, April, and May, 1923.

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antenna experiments. On September 16, 1923, Beverage, Dean, and Hansell at Belfast, Maine, transmitted alternately with a plain antenna and a wave antenna while Peterson at Riverhead, Long Island, measured the strength of received signal.

The wave antenna used in these tests was three wavelengths long and was terminated at the distant end in a resistance equal to the characteristic impedance. A wavelength of 1650 meters was used.

Considering the current flowing in the input end of the wave antenna the apparent effective height, as determined by the signal measured at Riverhead, was more than twenty times the actual height of the antenna wires. This indicated considerable directivity.

The signal from the wave antenna was only about a quarter of that from the plain antenna, for approximately equal power, indicating low radiation efficiency. Still this first result seemed promising and a considerable amount of time was spent by Hansell, during the first half of 1924, at Belfast in studying the wave antenna for transmission.

The observations and conclusions made during this period will be briefly summarized as follows:

(1) The wave antenna gives a simple structure with considerable directivity both horizontally and vertically. The beam from it is inclined upward at an angle to the earth. A single structure may be used over a wide range of wavelengths without tuning adjustments.

(2) Except for end effect the useful radiation from the wave antenna, when used for transmitting, takes place only due to wave tilt produced by losses and low velocity of that portion of the field around the wires which enters the earth. Reducing the resistance and radiation losses in the earth also reduces the useful radiation so that high radiation efficiency does not result.

(3) To obtain efficient radiation without waste of energy in the ground it is necessary to employ an antenna structure which will itself produce a wave tilt. Such a structure is one in which the conductors carrying the waves have attached to them a series of radiators at right angles. These radiators then carry currents at right angles to the direction of the wave motion on the antenna and radiation takes place.

(4) In a receiving wave antenna the space waves can build up a continually increasing energy in the antenna as they sweep over it because they have a higher velocity than the antenna waves and so continually advance in phase relative to the antenna waves. Thus the counter electromotive force of the waves on the antenna cannot prevent the transfer of energy, because of its lagging phase.

When the same antenna is used for transmitting the conditions are reversed so that as soon as energy is transferred to the space waves it

advances in phase relative to the waves on the antenna and tends to return to the antenna. From this it is evident that a transmitting wave antenna should have a wave velocity greater than the velocity of waves in the medium in which it is used. For antennas operated in air this means that we should have a velocity greater than light. We cannot obtain real velocities greater than light but we can produce a structure in

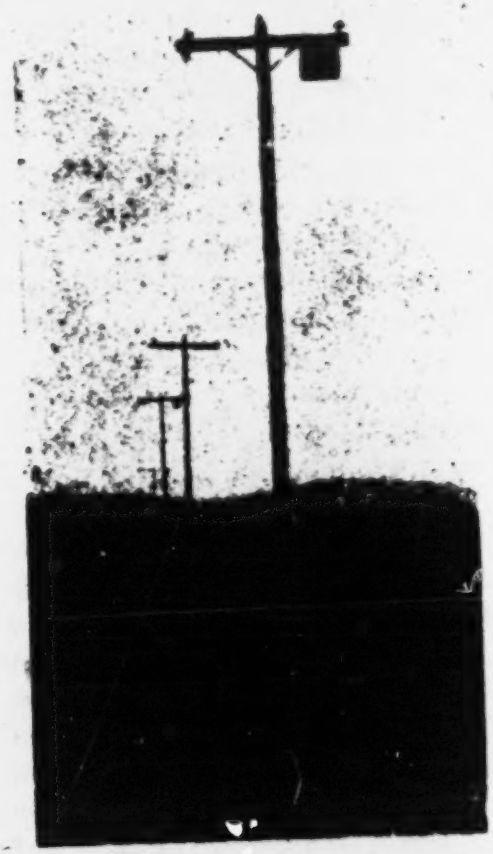


Fig. 1—Experimental wave antenna at Belfast, Maine.

which, under steady state conditions, we have an apparent or phase velocity greater than light.

(5) If a wave antenna can be given an actual velocity different from the wave velocity of the medium in which it is immersed this alone will produce a wave tilt which will result in radiation. If the actual velocity of waves on the antenna can be made greater than the velocity in the medium we can obtain considerable radiation, the amount of which increases with velocity, and which permits us to obtain very directive antennas which are also substantially aperiodic. Some interesting experiments have been made to bear out this theory by immers-

ing partially insulated radiator wires in water. In this case we do obtain an actual velocity on the wires greater than the velocity of waves in the water.

In a paper presented to the British Royal Society of Arts in July 1924,[4] Guglielmo Marconi gave publicity to his work on the development of directive short-wave systems. This stimulated world-wide short-wave development, and influenced us to undertake a careful first-hand study of the contemporary progress made in this field in England, Germany, and France. During, and immediately following this period, the engineering department of the Radio Corporation, directed by C. H. Taylor, was occupied with the development of suitable transmitting equipment, the application of this equipment to studies of propagation phenomena, and the establishment of commercial long-distance short-wave circuits.[5] The work during this period was primarily directed toward the development of efficient and reliable apparatus capable of meeting the exacting demands of short-wave communications. Meantime, the engineers of other companies associated with the Radio Corporation were working on the same problems.

The successful demonstration of the British beam circuit between England and Canada was made in 1926, proving the effectiveness of directivity. This result, together with completion of the initial apparatus development, caused us to concentrate on our study of propagation phenomena, and the development of directive antenna systems which would be efficient and sufficiently inexpensive to permit their use on a great number of our commercial long-distance circuits.

Lindenblad, who had specialized on antenna design, was added to the Rocky Point group to work exclusively on directive antenna development. He had assigned to assist him, at various times, Henry Tanck of the R.C.A., and C. F. Coombs and Paul Forrest of the General Electric Company.

In the four years which followed, four types of directive antennas were developed. These have been designated as Models A, B, C, and D. The model A system is of the broadside type, consisting of linear arrays of vertical radiators fed with a special transmission system having nearly infinite phase velocity. The model B antenna consists of one or more arrays of parallel long wires, in a vertical plane, which have their ends staggered in such a way as to give a unidirectional beam of ver-

[4] Guglielmo Marconi, "Results obtained over very long distances by short wave directional wireless telegraphy, more generally referred to as the beam system," read at a meeting of the Royal Society of Arts, July 2, 1924.

[5] Hallborg, Briggs, and Hansell, "Short-wave commercial long-distance communication," Proc. I.R.E., 15, June, 1927; H. E. Hallborg, "The radio plant of R.C.A. Communications, Inc.," Proc. J.R.E., 18, March, 1930; A. A. Isbell, "The RCA world wide radio network," Proc. I.R.E., 18, October, 1930.

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tically polarized waves. The model C antenna is similar to the model B but differs in that the radiator wires are arranged in a horizontal plane and give a unidirectional beam of horizontally polarized waves. The model D antenna system consists of radiating elements made up of long wires bent into the shape of horizontal V's which are used in an array giving a unidirectional beam of horizontally polarized waves.

Development of the Model A Antenna

The development first followed the ideas brought out at Belfast, in that efforts were directed toward obtaining an efficient form of transmitting wave antenna. Great difficulty was encountered in attempting to control the velocity, current distribution, and radiation efficiency of wave antenna models.

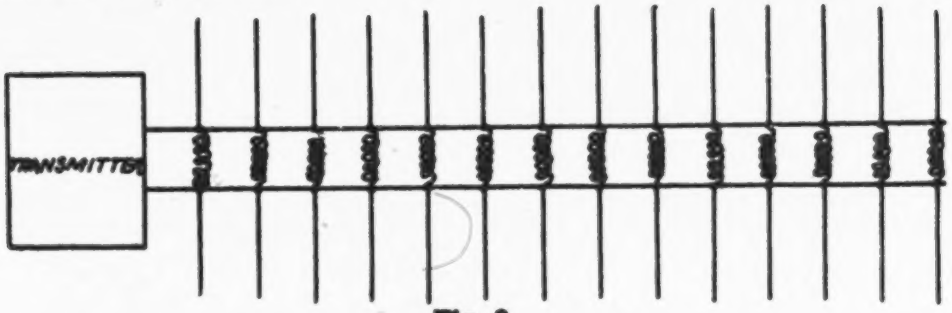


Fig. 2

In the course of the experiments there was erected a type of wave antenna similar to that shown in Fig. 2. In this antenna two parallel feeder lines or buses served to carry the waves. Attached to these feeders at frequent intervals were radiator wires set at right angles to the feeders. Across the feeders, at the radiator positions, were inductance coils intended to balance out the capacity of the radiators and a sufficient part of the feeder capacity to give a phase velocity slightly greater than the velocity of light.

In working with this model the procedure was to vary the phase velocity by varying the transmitter frequency. The current distribution in the antenna was checked and the field distribution pattern of the radiation was measured with a portable receiving antenna and sensitive thermocouple meter.

It was soon observed that if the frequency was sufficiently decreased, a point was reached where the phase velocity was substantially infinite and a good directive pattern, approximately at right angles to the antenna, was obtained. This broadside directivity was obtained so much more readily than the wave antenna effect that it was decided to build a full-scale working model of unidirectional antenna using this principle and to try it out for long-distance transmission.

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The model was finished and first demonstrated by transmission from Rocky Point, New York, to Marshall, California, and Koko Head, Hawaii, on April 3, 1927.

An analysis of the power increase per unit cost for this type of antenna indicated that it could compete successfully with the British beam and other existing forms of directive antennas. It had a marked advantage in meeting our needs and permitted improvements in service by application of directivity to a large number of circuits at a moderate expense. Its use did not require risking a large loss of investment in antennas due to obsolescence.

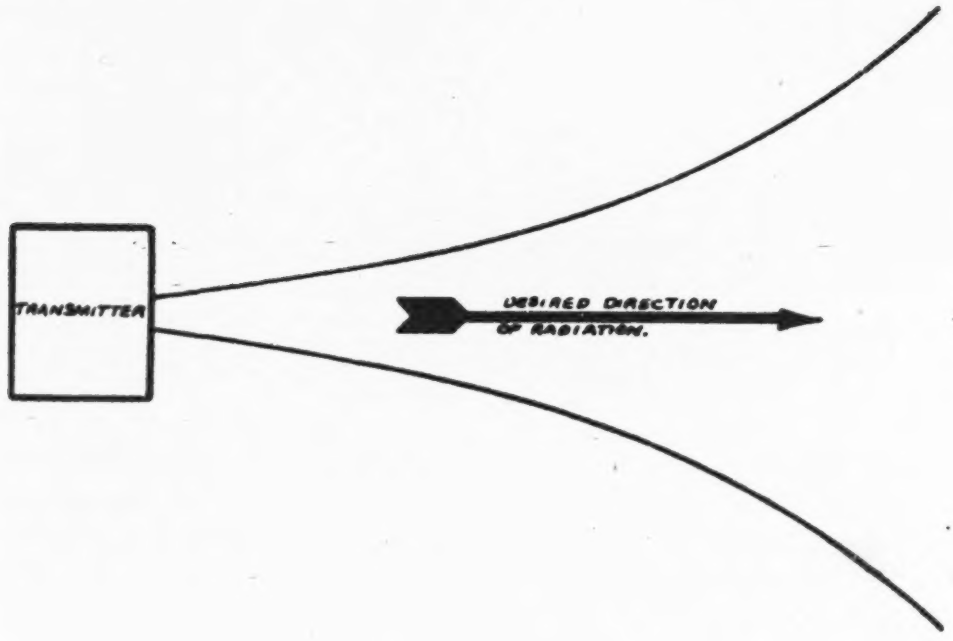


Fig. 3

The first commercial Model A antenna went into service in September, 1927. It was operated on a 16.2-meter wavelength and used the call letters 2XT and WTT. It was directed at Germany but was also useful to several other points in Europe. It soon proved itself to be a valuable addition to service and was operated successfully at traffic speeds up to 240 words per minute.

The designs of the first commercial Model A antenna system and additional antennas which were built in rapid succession were handled by Carter. Altogether 38 antennas of this type have been built and are still in use in the United States, Phillippines, Hawaii, China, Russia, and Norway.

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Developments of Models B and C Antennas

During most of the period occupied by the demonstration and commercialization of the Model A antenna, in 1927 and 1928, Lindenblad was kept as free as possible to continue the forward looking development aimed at producing some practical form of transmitting wave antenna. During this period J. A. Biondo[6] was his chief assistant.

Among other ideas investigated an attempt was made to obtain radiation attenuation and directivity from a transmission line having a continuously changing characteristic impedance or a continuously changing spacing as shown in Fig. 3. The idea behind the increasing spacing was to obtain a wave tilt to produce radiation and it was hoped that sufficient attenuation might be obtained to give us an aperiodic antenna with practically a unidirectional characteristic.

In these particular experiments the results with the expanding line antenna were not very satisfactory because the attenuation was not sufficiently great. However, they served to focus attention on the radiation efficiency and directive characteristics of long wires and caused Lindenblad to consider ways of combining them to obtain sharp unidirectional characteristics. As a result he devised the directive system employed in the models B and C projector antennas. A complete description of these models is given later in this paper. For a general idea of the form of construction used refer to Figs. 22 to 26.

A small model of his antenna system, which could be made vertical to correspond to the Model B or horizontal to correspond to the Model C, was built and tested on a six-meter wavelength with promising results. At the same time Carter was following up Lindenblad's experiments by mathematical calculation and analysis. Carter's results, in general, confirmed the experimental measurements. It was therefore decided to build full-scale models for test and demonstration between Rocky Point and Marshall.

The first large Model B antenna had been constructed and tuned by February 7, 1929 and long-distance tests were started on that date. From that time until about the first of April a series of tests was made resulting in improvements in the original model in respect to radiation efficiency and angle of the beam. At the same time information was collected to enable us to design commercial antennas with dimensions which would result approximately in optimum results per dollar of cost. The final results indicated that the new antenna would be a great improvement over the Model A not only in results per dollar of cost but also in simplicity and service reliability.

[6] Mr. Biondo is now representing the R.C.A. in Italy in connection with the erection of a broadcast station in Rome.

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During the early tests and demonstrations of the Model B antenna a Model C antenna was being constructed. It was finished and first used for long-distance tests on April 10, 1929. It was also carefully studied with the object of obtaining optimum economy in design and it too was found to be a great improvement over the Model A.

Since Model B and C antennas were ready for application to commercial construction at about the same time, it became necessary to make a choice between them. Upon first consideration it appeared that

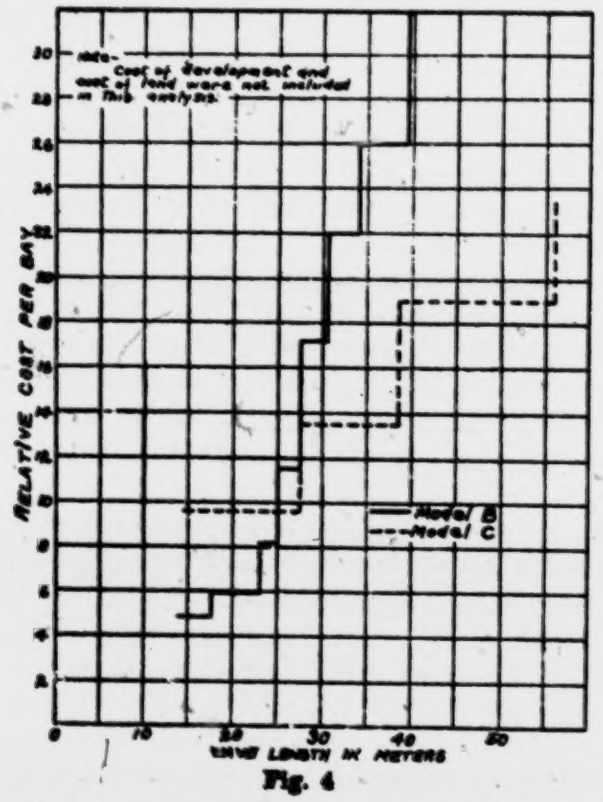


Fig. 4

one model would be discarded but an analysis of the gain in energy at the distant receiver per dollar of cost at the transmitter for various wavelengths indicated that both models should be used. The results of this analysis are shown graphically in Fig. 4. The vertical model B antenna was found to be more economical on wavelengths below 25 meters but more expensive than the horizontal Model C antenna on longer waves.

It was fortunate that this was true because the Model B antenna is better suited to increasing directivity by broadsiding several antennas to form one very directive system. A single section has sharp vertical directivity but its beam is quite broad horizontally. The broadsiding

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increases only the horizontal concentration and this can be done without making the beam excessively narrow.

The beam from the Model C antenna, on the other hand, is broad vertically but very sharp horizontally, making it less suitable for broadsiding. Since the cost per section of directive antennas is high on the longer waves, where the Model C is used, there is less need for broadsiding a number of sections and the objection to the use of the Model C antenna is unimportant.

The first commercial Model B antenna was placed in service at Rocky Point on April 4, 1930. It has two broadsided sections directed on Madrid and is used on a 16.55-meter wavelength. Altogether there have been or are being built twenty-five of these antennas at Rocky Point, New York, New Brunswick and Tuckerton, New Jersey, Bolinas, California, and in the Hawaiian Islands. Sixteen of these antennas are being built by the Mutual Telephone Company of Honolulu. They are to be used for both transmitting and receiving in the system of telephone circuits to connect the islands on wavelengths of less than 10 meters.

The first commercial Model C antenna was placed in service on July 7, 1930. It has only one section, is directed on Buenos Aires and is used on a 28.22-meter wavlength. Altogether six of these antennas have been built at Rocky Point and New Brunswick.

Development of the Model D Antenna

For a brief period the engineers of the group were inclined to believe that the Models B and C came close to the ultimate in simplicity and economy and that little further improvement was attainable. There being no further ideas recognized as holding promise of immediate economic gain, Lindenblad was assigned to carry on pioneering development in another field.

Carter, with the assistance of E. D. Thorne, continued the design of antennas for commercial construction. Some of his time was given to extended tests with the Models B and C, and to further mathematical analysis with the object of obtaining a better understanding of experimental results. He immediately became interested in other combinations of long wires for obtaining directivity and, before the end of 1929, was advocating the trial of a new type of antenna which, by requiring fewer supports, promised to have an economic advantage over the three previous models. This antenna, which has some resemblance to the expanding line shown in Fig. 3, is now known as the Model D. For a general idea of its construction refer to Fig. 36.

An experimental Model D antenna was built in the first part of 1930

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and long-distance tests were started in April. These tests were continued throughout the summer and fall and have resulted in the adoption of the Model D for new construction. At the present time there are built, or being built, eleven antennas of this type located at Rocky Point, New York, Bolinas, California, and Kahuku, Hawaii. The antennas at Kahuku are of particular interest because they will be used as part of the first commercial transoceanic telephone station to be operated by R.C.A. Communications, Inc.

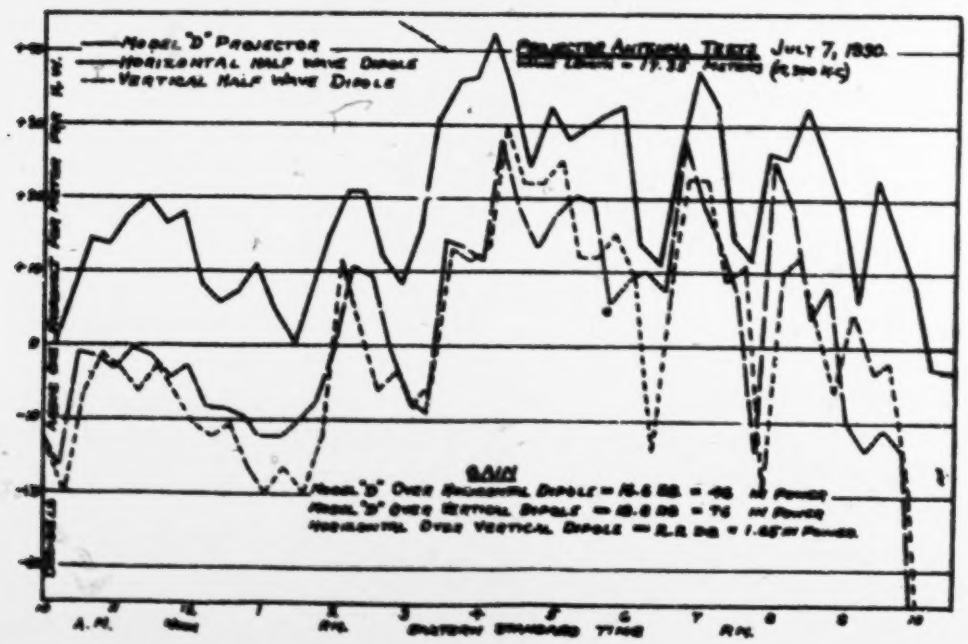


Fig. 5

Method of Testing Antennas

All of the long-distance antenna tests have been made by switching the transmitter from one antenna to another, usually at five-minute intervals. A half-wave dipole at the same height and having the same polarization as the directive antenna under test has been used as a standard of reference. In addition, many tests have been comparisons of one model of directive antenna with another.

In all cases the transmitter power has been measured for each reading by subtracting the power carried away in the cooling water from the input to the last stage of amplifier.

The relative signal strength delivered to the receiver by the antennas being compared has been measured with a calibrated receiver in the

output of which a meter was used as an indicator to average out rapid fluctuations and eliminate possible errors in judgment of the operator.

The readings have been reduced to decibels above an arbitrary reference value, per kilowatt of transmitter power. The average received signal energy in decibels for the whole day is then determined for each of the antennas under test and the difference between these figures, which is ten times the logarithm of the power ratio, is taken as

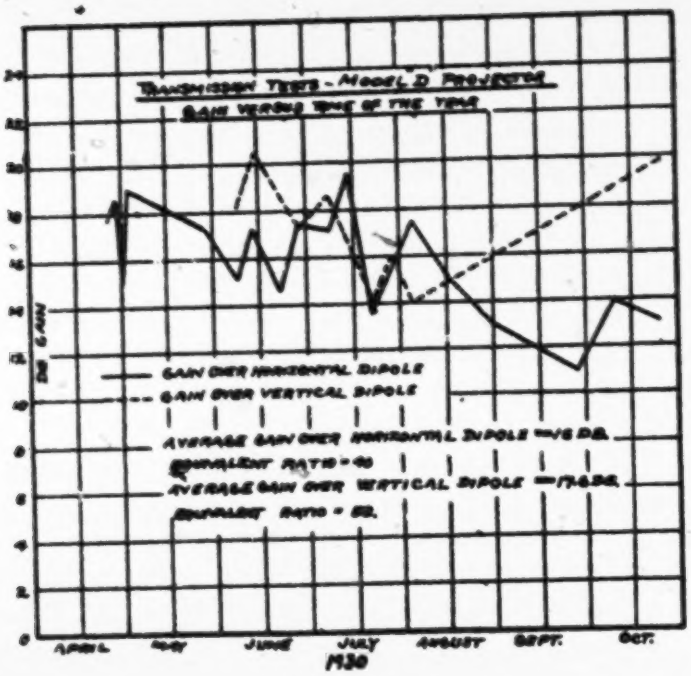


Fig. 6

the difference in effectiveness of the antennas on that day. We consider this the best method of arriving at a ratio for the extremely variable signals from short-wave antennas.

Fig. 5 shows the results of a typical day's run on a Model D antenna. Many days of tests of this sort have been made to arrive at a reliable figure of merit for each model.

Fig. 6 shows the seasonal variation in effectiveness of the Model D antenna when used for transmission from Rocky Point to Marshall on a wavelength of 17.3 meters.

We are greatly indebted to R. R. Beal of the Pacific Division and his staff, particularly I. C. Reid of the Marshall Station, for their cooperation in making thousands of signal strength measurements. The remarkable consistency of the average results in spite of the great variations in individual readings on short-wave signals indicates extraordinary care and patience on their part.

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Power Concentrations Obtained

The increase in power, due to antenna directivity, of the signal received at a distant receiving station varies to some extent with the wavelength, time of year, and the particular circuit being observed. Our long-distance tests have, in most cases, been made on wavelengths of 16 to 17 meters and over the transcontinental circuit from Rocky Point to Marshall. Some additional tests have been made over the longer circuit from Rocky Point to Hawaii. The Model A antenna was tested by comparison with a half-wave dipole for transmission from Rocky Point to Geltow, Germany. These tests checked the measurements made at Marshall with remarkable exactness.

The directivity of the Model A antenna was also checked by comparison measurements with a pick-up antenna and a sensitive thermocouple meter located at from 500 to 2000 meters in front of the dipole and directive antenna. These short-distance measurements checked the long-distance measurements at Marshall and Geltow within 10 per cent.

Using the average of a great number of experimental determinations we have arrived at the following approximate figures for the increase in power, due to directivity, from one bay of each of the four models of directive antennas.

	Decibels Gain Over Half-Wave Dipole	*Power Ratio To Half-Wave Dipole*	*Directivity*
Model A	10	10	16.4
Model B	12	16	26.3
Model C	13.4	17.5	28.7
Model D	16	40	65.6

Where a number of bays is used the increase in power ratio is very nearly in proportion to the number of bays. We have used up to four bays of the Model A, two bays of the Model B, two bays of the Model C, and two bays of the Model D. This does not mean that no greater directivity should be used, and further discussion on this point will appear later in the paper.

Study of Directive Characteristics Required

In all of the directive antenna development we have been troubled by lack of reliable information as to what directive properties an antenna should have. The uncertainties in this connection, which must also have troubled others, may be briefly summarized in the following questions:

(1) Should the beam from a directive antenna be made up of vertically polarised waves or would horizontal polarization be better?

(2) If unlimited vertical directivity is obtainable, how sharp should this directivity be made and what should be the angle of elevation of the beam with respect to the earth?

(3) Does the beam of radiation always follow the great circle path from transmitter to receiver or may it be variably deflected due to unequal refraction in the atmosphere in such a manner that very sharp horizontal directivity should not be used?

We must admit that we cannot give complete and reliable answers to these questions but we have obtained some information of practical value and have formed tentative conclusions which may be of interest to others.

In the early tests with Marshall and Koko Head a comparison was made of the signals delivered from horizontal and vertical dipoles. It was found that the horizontal dipole delivered considerably more power to Marshall but the vertical dipole was better by about an equal amount at Koko Head. Since Marshall is about 2600 miles and Koko Head 5,000 miles distant from Rocky Point, we concluded that difference in polarization was probably unimportant except in so far as it might affect the transmitting antenna efficiency and directivity. It might have a considerable effect upon the wavelength which would give best results over a given circuit at a given time of year and time of day but, throughout a year and averaging all conditions, would probably have little effect upon the average usefulness of an antenna. In general, it appears that horizontal polarization should be used on shorter circuits, or on shorter wavelengths than should vertical polarization. However, the data available are too meager to permit a reliable conclusion.

The Model B antenna has probably the greatest vertical directivity obtained in any commercial form of directive antenna. In a series of tests extending over about six months no evidence of widely varying power ratios from the sharp directivity was observed at Marshall. We are, therefore, inclined to believe that vertical directivity of the amount used in this antenna is safe so long as the correct angle of beam is used.

Since the vertical directivity of the Model B antenna is so great, it gave an opportunity to make an experimental check on the effect of elevation of the beam upon the signal received at a distance. Originally the British Marconi Company had given a rather high angle as the optimum elevation for the radiation and had indicated that their beam antennas were designed to give this high angle. Subsequently T. L.

Eckersley made a very complete and ingenious study of this problem from data obtained by facsimile transmission using vertically polarized waves and concluded that quite small angles should be used.[7] Miessner and Rothe, in Germany, arrived at the same conclusion by means of experiments with horizontally polarized waves.[8]

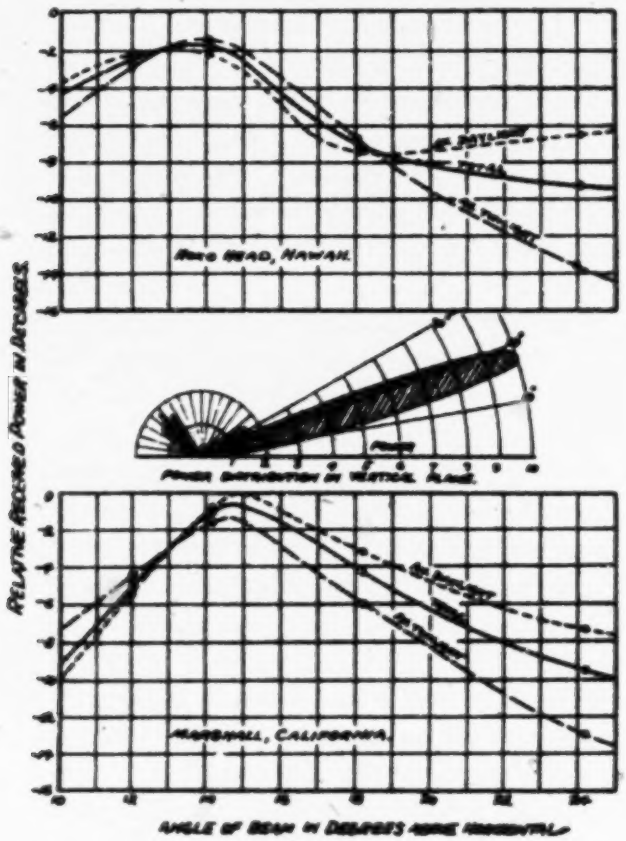


Fig. 7

Our experiments with the Model B antenna, which is vertically polarized, checked the conclusions of Eckersley and Miessner. The experimental results were more striking than those of Miessner because of the very sharp directivity of the Model B antenna.

In making our tests the elevation of the beam was varied by changing the angle of the antenna. For each angle the signal from the directive antenna was compared at Marshall and Koko Head with another antenna used as a standard. The results of the tests are shown in Fig. 7. In this figure the relative signal strengths are plotted against the true

[7] T. L. Eckersley, "Multiple signals in short-wave transmission," Proc. I.R.E., 18, 106, et. seq.; January, 1930.

[8] Miessner and Rothe, "On the determination of the optimum radiation angle for horizontal antennas," Proc. I.R.E., 17, 35, et. seq.; January, 1929.

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angle of the line of maximum radiation. The sharpness with which the signal rose at Marshall may be partly due to increasing directivity from ground reflection but still it is obvious that the energy which reached the receiving station left the transmitting antenna at some low angle. The decrease in signal at very low angles is believed due to decreasing radiation efficiency and increasing ground losses near the transmitting antenna because, to get the lowest angle, the lower end of

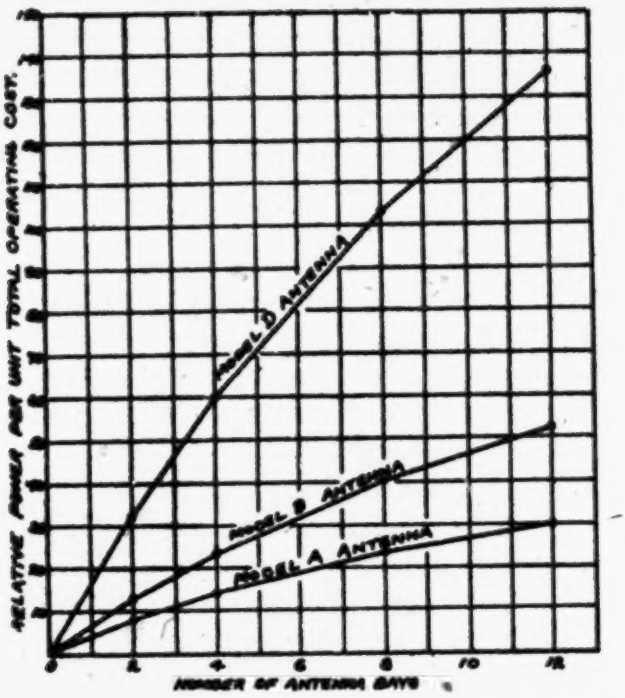


Fig. 8

the lowest radiator wire had to be run in a trench below the surface of the ground.

It will be noted that the lowest possible elevation of the beam which does not produce excessive losses in the ground is best. It may also be noted that the results at the two different distances are remarkably alike, indicating that the lowest obtainable angle is probably best for a large range of distances. Since horizontal radiation is cancelled by radiation reflected from the ground, it will be observed that the lowest obtainable angle for the center of the beam is several degrees above horizontal.

In connection with the third question we have never failed to obtain an improvement in proportion to the number of broadsided bays with any of the antenna models, except for one or two very rare and short periods. The observers at Marshall have not been able to detect any

difference in fading between a plain dipole and any of the directive antennas. It, therefore, seems probable that horizontal deflections of the beam, although they probably exist, are usually so small as to permit the use of great horizontal directivity.

Economic Value of Directive Antennas

From an engineering point of view, the money spent upon a transmitting station for interest on investment, depreciation, power, taxes, operating personnel, etc., is chiefly for the purpose of delivering signal power to the input of the distant receiver. If, by using a directive antenna, the power delivered to the receiver can be greatly increased with relatively small increase in cost, the value and efficiency of the entire investment is greatly increased.

As an illustration of the way in which our directive antennas can be used to increase the value of a transmitting station having only one 20-kw transmitter operating on a wavelength of about 20 meters, refer to Fig. 8. In this figure is shown the calculated relative received power per dollar of total cost at the transmitter for various numbers of bays of each of three types of antenna.

These curves have been calculated on the assumption that the received power is increased in proportion to the number of bays used. We have proven this to be true up to four bays of the Model A and two bays of the Models B, C, and D. Since the economic value of directivity is so great, it is obvious that a large antenna system should be used. It is hoped that data can soon be made available to show the limit beyond which the received power does not increase in proportion to the size of the antenna and the way in which the results depart from proportionality.

In applying the curves of Fig. 8 to the design of any particular transmitting station, consideration must be given to many special factors which may affect the particular station. For example, if the station is required to handle traffic to two or more receiving stations at different angles, it may be more economical to use one high power transmitter on a relatively small antenna than to use several lower power transmitters on large antennas. For an operating agency handling many circuits from one point, such as R.C.A. Communications at New York and San Francisco, the benefit from large directive antennas must be balanced against the advantages of placing a large number of transmitters in one building. The number of transmitters in one building and the size of antennas determine the length of radio-frequency transmission lines which must be used. The power losses in these lines must be considered in designing for optimum over-all economy of operations.

From a slightly different point of view it may be noted that directive antennas make it possible to increase greatly the maximum obtainable signal power. At the present stage of development, 40 kilowatts is about the maximum practical power from any short-wave transmitter and this power radiated from a plain antenna might be insufficient for making some radio circuits commercial. By using a two-bay Model

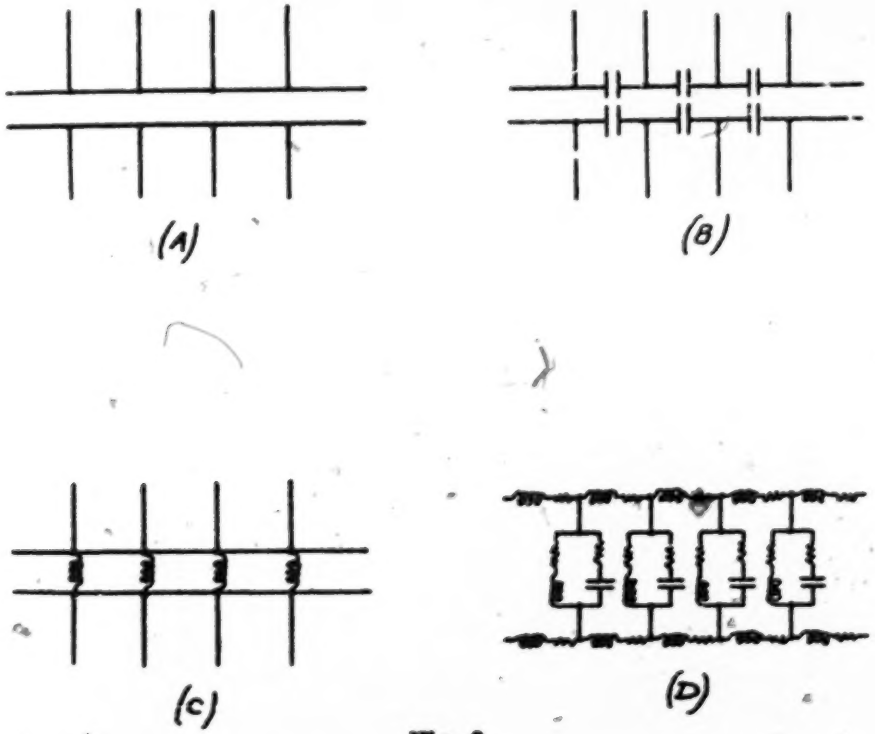


Fig. 9

D antenna, instead of a plain antenna, with a 40-kw transmitter, we may obtain an intensity in one direction equivalent to 3200 kilowatts.

It is conceivable that, before many years, the most important radio circuits may be equipped with transmitters and antennas capable of concentrating radiation in one direction equivalent to that which would be obtained in this direction with 25,000 kilowatts in a nondirective antenna.

Description of the Model A Antenna

This antenna is one in which linear arrays of vertical radiators are used. See Figs. 9 and 10. The features connected with the feeding of the radiating elements are somewhat unique. All radiators are fed in phase by a common feed line or bus system. In order that the radiators may be fed in phase, it is necessary that the velocity of phase propagation on the feed line be infinite. This does not mean that the feed energy

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travels along the line at any such velocity. It merely means that by certain tuning procedure a phase phenomena can be produced which would be obtained were it possible to attain actual infinite wave velocity. Since the tuning and loading of the line is done with lumped values at regularly spaced intervals it may be proper to look at this antenna as a network rather than as a line. The choice of either viewpoint is a



Fig. 10—Four-bay model A antenna.

matter of personal taste. It may be well to use both to obtain a conception which conforms more closely with what actually takes place.

In Fig. 9, (A) represents the radiating elements attached to a common feed line. In order to obtain the correct phase of the individual radiators, the line must be broken up by series condensers as shown in (B) or shunted by inductances as shown in (C). The use of shunt coils was preferred for practical reasons. In diagram (d) we have shown the equivalent network of arrangement (C). The method of obtaining infinite phase velocity along the feeder system is similar to that used in the Alexanderson multiple tuned antenna. In the case shown in (C), (D) the phase velocity is made to approach infinity by balancing out all capacity by means of inductive shunt reactances.

The determination of optimum constants in the design of this an-

tenna system was too complicated to be solved entirely by theoretical calculations and the dimensions adopted were arrived at chiefly by experiment. It was necessary to balance radiation efficiency against the length of the antenna which could be fed from one point, by proper choice of the length of radiators and the electrical constants of the feed line. The values finally arrived at are as follows:

Length of radiators (over-all)	0.225	wavelength
Spacing between radiators	0.125	"
Maximum length of bus on each side of feed point	1.5	"
Volt ampere ratio between bus and radiators	5.	

The antenna is so designed that sleet melting current can be applied without interruption of operation.

In order to cover the necessary variation of tuning between certain standard dimensions of inductance coils, it was found convenient to make the capacity of the bus variable. This was accomplished by making each side of the line of two strips, the spacing of which was variable.

The complete antenna system includes two parallel rows of radiators placed at a spacing of five quarter wavelengths. Energy is fed to both rows of radiators of such a phase as to make the system unidirectional. The relatively large spacing between antenna and reflector elements is beneficial in reducing coupling between them. This reduces the difficulty of making the tuning adjustments and does not detract from the power gain due to directivity where both the antenna and reflector are fed from transmission lines.

The total gain in power per section of this antenna is 10 as compared with a half-wave dipole. Such a section is called a bay. We have not gone into detail in describing the action of this antenna because the general principles involved have been fully covered by Southworth.[9]

It has been found feasible to use open-wire transmission lines for feeding these antennas.[10] They compare favorably in efficiency with other types of lines. The possibility of undesired coupling between the antennas and the lines can be avoided by adherence to symmetry and selection of neutral planes in the vicinity of the antenna.

Principles of Long Linear Radiators Used in Antenna Models B, C, and D

The principles involved in the action of the three antennas whose descriptions are to follow are more or less similar and are based upon

[9] G. C. Southworth, "Certain factors affecting gain of directive antennas," Proc. I.R.E., 18, 1502–1536; September, 1930.

[10] N. Lindenblad and W. W. Brown, "Main considerations in antenna design," Proc. I.R.E., 14, 291 et. seq.; June, 1926.

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the characteristics of a straight wire several wavelengths long. For this reason we shall discuss these characteristics in detail.

(a) Distribution of Radiation

It is well known that maximum radiation from a very short dipole or Hertz doublet takes place at right angles to the axis of the doublet and that the radiation in the line of the axis is zero. At a constant dis-

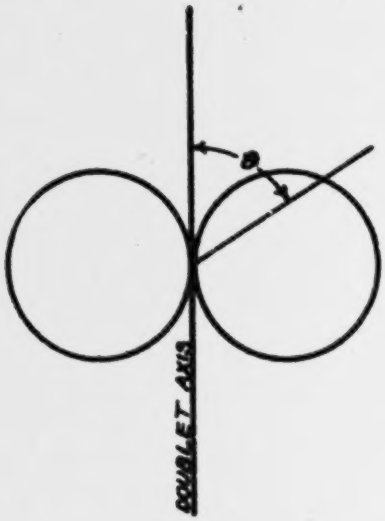


Fig. 11

tance the field intensity of the radiated wave is proportional to the sine of the angle to the axis. The plane polar diagram of relative field intensity is thus a figure eight as shown in Fig. 11. Since in a pure travel-

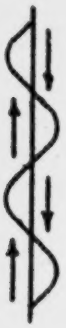


Fig. 12

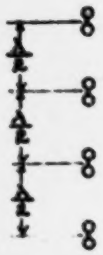


Fig. 13

ing wave the electric and magnetic intensities are equal and the intensity of energy flow is proportional to the square of either, we shall consider the electric intensity only in this discussion.

The fundamental natural frequency of oscillation for a wire in space is $c/2L$ where c is the velocity of light and L the length of the wire. Such

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a wire also has natural periods corresponding to *all* multiples of the fundamental frequency. Thus the ratios of the length of the wire to the natural wavelengths are 1/2, 2/2, 3/2, 4/2, etc. The instantaneous values of the current along a wire having a length of two waves are as shown in Fig. 12. The wire is equivalent to four half-wave dipoles placed end to end with the current reversed in each succeeding dipole. For a qualitative analysis let us replace each half-wave dipole by a doublet as shown in Fig. 13. The radiation pattern of a doublet is sufficently near that of a half-wave dipole for present purposes.

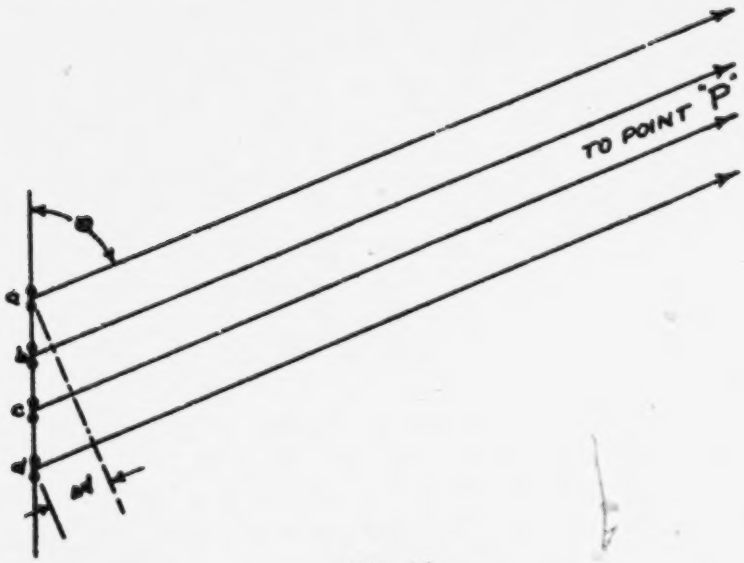


Fig. 14

Let us now go to a point P, Fig. 14, whose distance from the wire is so great in comparison with the length of the wire that the paths of wave travel may be considered parallel. The total instantaneous field at P must be the sum of the instantaneous fields due to the doublets. If the direction of P is at right angles to the wire, the field from each doublet is a maximum. Call this E. In other directions at the same distance, the field intensity for one doublet is $E \sin \theta$. Now, the distances from each doublet to P are unequal and, due to the fact that the waves travel with the velocity of light, the wave fronts will arrive at different times.

This difference in time is equivalent to a phase angle. There are similar phase differences between the waves from b and c with respect to a. The effective value of the total field at P is the vector sum of the four components.

In the direction at right angles to the axis, ($\theta = 90$ degrees) the total intensity is zero. In either direction along the axis the phase

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angles between components are zero and the resultant intensity would be a maximum were it not for the fact the intensity of each component is zero. By calculation we would find a maximum at approximately 36 degrees, zero at 60 degrees, and a second maximum of lower intensity than the first at about 75 degrees.

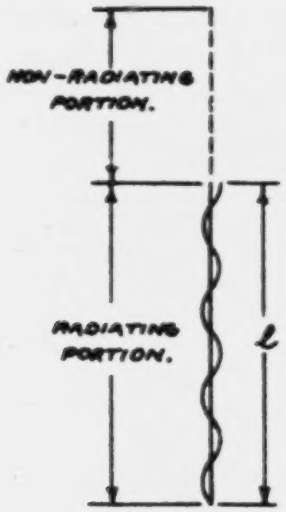


Fig. 15

Abraham[11] has treated the case of a grounded wire oscillating at one of its natural frequencies while Pierce[12] has quite completely analysed the grounded L antenna. Although the case of a wire free in space is similar in many respects to the cases already treated, it will nevertheless be analysed in detail here.

Consider a wire, the radiating portion of which has a length l. Assuming sine wave distribution the instantaneous current relationship is as shown in Fig. 15. Measuring the distance X from the free end of the wire, the current is

$$i = I \cos \omega t \sin \frac{2\pi x}{\lambda} \tag{1}$$

where $I \cos \omega t$ is the current at the antinode. Let us consider the wire as being made up of a large number of very short elements of length dX and determine the electric field e at a point P on an imaginary sphere whose radius r_0 from O is so great in comparison with the length of the wire that lines from any points on the wire to P may be considered parallel. (See Fig. 16.)

The wave from dX will arrive at P head of the wave from O due to its traveling a distance r which is less than r_0 by the amount $X \cos \theta$.

[11] *Phys. Zeit.*, 2, 1904.
[12] Electric Oscillations and Electric Waves.

A disturbance originating at O at the time t will arrive at the time $t+r_0/c$ where c is the velocity of light. Hence a wave represented by $E \cos \omega t$ at O will be represented by $E \cos [\omega(t+r_0/c)]$ at P.

At great distances from the wire the electric and magnetic fields are equal. It can be shown from the electron theory[13] that the magnetic field at any distance is the curl of Ψ where Ψ is the vector potential. At a great distance

$$\text{curl } \Psi = \frac{\delta \Psi}{\delta r} \sin \theta \tag{2}$$

if we neglect $1/r^2$ as compared to $1/r$.

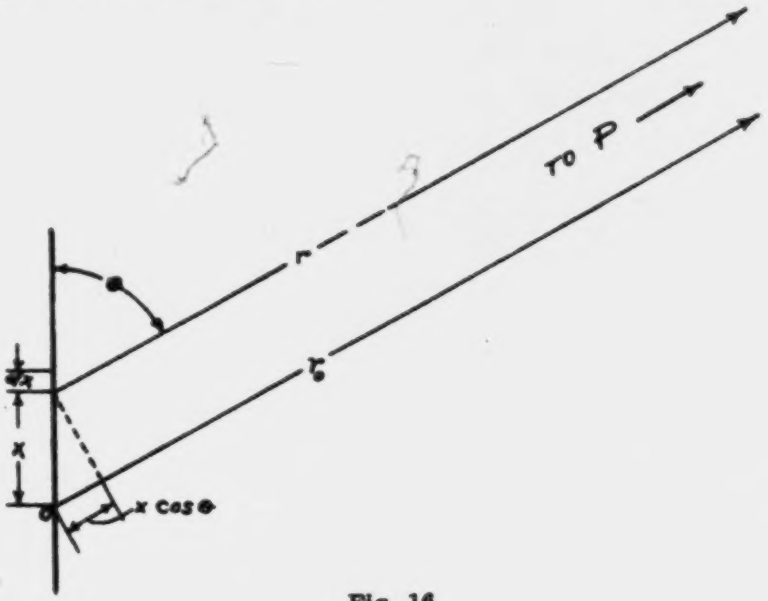


Fig. 16

Now,

$$\Psi = \frac{1}{c} \int_0^l \frac{[i]}{r} dx \tag{3}$$

where $[i]$ means that the time of travel must be properly taken into account. Hence

$$e = H = \text{curl } \Psi = \sin \theta \frac{\delta}{\delta r} \int_0^l \frac{I}{cr_0} \cos \omega \left(t - \frac{r}{c} \right) \sin 2\pi \frac{x}{\lambda} dx. \tag{4}$$

To simplify operations let $\cos \omega t$ be represented by the real part of $\epsilon^{j\omega t} = \cos \omega t + j \sin \omega t$. Then, since $\sin z = \epsilon^{jz} - \epsilon^{-jz}/2$

[13] *See* Jeans', Electricity and Magnetism, or other treatments of electromagnetic theory.

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$$e = \frac{I}{2j\lambda c r_0} \sin\theta \int_0^l \frac{\delta}{\delta r}\left[e^{j\omega(t-r/c)}\left(e^{j2\pi x/\lambda} - e^{-j2\pi x/\lambda}\right)\right]dx$$

$$= \frac{\pi I}{\lambda c r_0} \sin\theta \int_0^l e^{j\omega(t-r/c)}\left[e^{j2\pi x/\lambda} - e^{-j2\pi x/\lambda}\right]dx. \tag{5}$$

Since,

$$r = r_0 - x\cos\theta, \omega\left(t - \frac{r}{c}\right) = \omega\left(t - \frac{r_0}{c}\right) + 2\pi\frac{x}{\lambda}\cos\theta,$$

and,

$$e = \frac{\pi I}{\lambda c r_0} \sin\theta e^{j\omega(t-r_0/c)} \int_0^l \left[e^{j2\pi x/\lambda(1+\cos\theta)} - e^{-j2\pi x/\lambda(1-\cos\theta)}\right]dx \tag{6}$$

and, after performing the integration and several transformations, this becomes, after letting $2\pi l/\lambda = L$,

$$e = (I/cr_0)e^{j\omega(t-r_0/c)}\{\cos L\cos(L\cos\theta) + \cos\theta\sin L\sin(L\cos\theta)$$
$$- 1 + j[\cos L\sin(L\cos\theta) - \cos\theta\sin L\cos(L\cos\theta)]\}/\sin\theta. \tag{7}$$

When l is an even number of half waves $L = 2K\pi$ where K is an integer and,

$$e = \frac{2I}{cr_0}\cos(\omega t - \beta)\frac{\sin\left(\frac{L}{2}\cos\theta\right)}{\sin\theta} \tag{8}$$

When l is an odd number of half waves $L = (2K-1)\pi$ then $\cos L = -1$, and,

$$e = \frac{2I}{cr_0}\cos(\omega t - \beta)\frac{\cos\left(\frac{L}{2}\cos\theta\right)}{\sin\theta} \tag{9}$$

If n is the number of half waves on the wire $L = \pi n$ and $L/2 = n\pi/2$.

Hence, if E is the amplitude of e, we have the following two relations:

$$E = \frac{2I}{cr_0}\frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \tag{10}$$

when the wire is an even number, n, of *half* waves long and

$$E = \frac{2I}{cr_0}\frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \tag{11}$$

when the wire is an odd number, n, of *half* waves long.

Formula (7) is perfectly general and from it can be determined the field for any length whatever, but, for simplicity, we shall consider only the cases where the length is an exact multiple of a half wave.

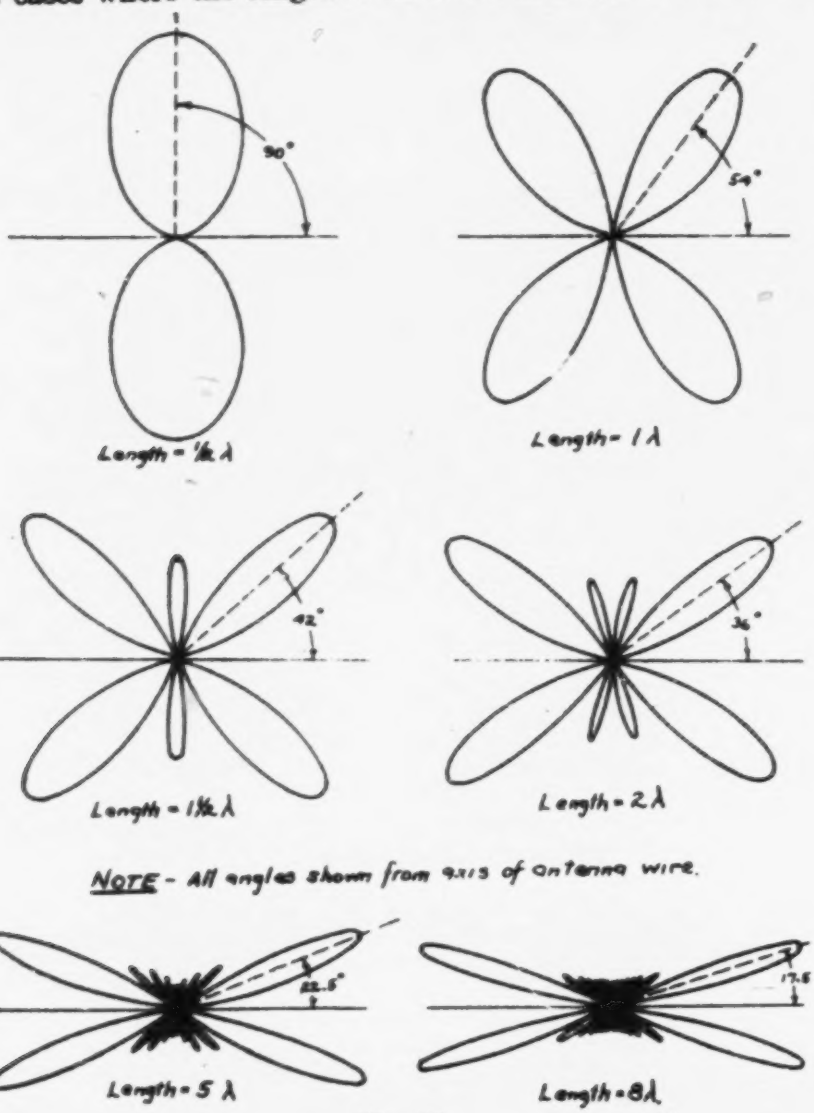


Fig. 17

Since the power flow is proportional to the square of the field amplitude, relative power distribution is obtained by squaring the values of E given by (10) or (11).

For any particular length of radiator we wish to know the angles of maximum radiation, the angles of zero radiation, and the relative amplitudes of the maxima. When n is even, for E to be zero:

$$\sin\left(n\frac{\pi}{2}\cos\theta\right) = 0, \quad n\frac{\pi}{2}\cos\theta = k\pi$$

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where k is an integer and,

$$\cos\theta = 0, \frac{2}{n}, \frac{4}{n}, \cdots, \frac{n}{n} \tag{12}$$

When n is odd, for E to be zero:

$$\cos\left(n\frac{\pi}{2}\cos\theta\right) = 0, \quad n\frac{\pi}{2}\cos\theta = (2k-1)\frac{\pi}{2},$$

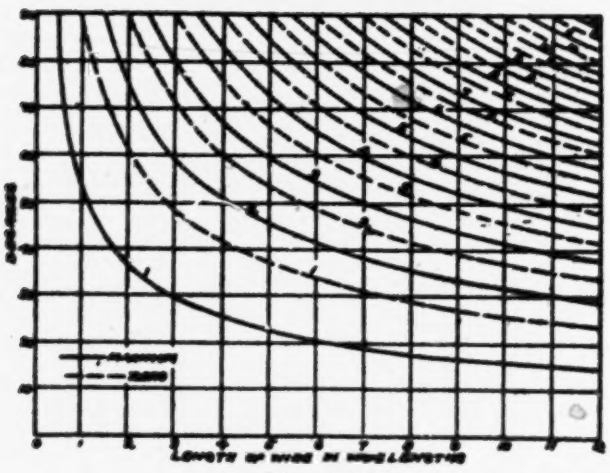


Fig. 18

and,

$$\cos\theta = \frac{1}{n}, \frac{3}{n}, \frac{5}{n}, \cdots, \frac{n}{n}. \tag{13}$$

When E is a maximum $dE/d\theta = 0$ from which we obtain:

$$\tan\left(n\frac{\pi}{2}\cos\theta\right) = -n\frac{\pi}{2}\tan\theta\sin\theta \tag{14}$$

when n is even, and,

$$\tan\left(n\frac{\pi}{2}\cos\theta\right) = n\frac{\pi}{2}\tan\theta\sin\theta \tag{15}$$

when n is odd

The values of θ for which E is maximum are obtained by solving these two equations graphically. The relative amplitudes of the maxima are obtained by substituting the values of θ obtained from (14) and (15) in (10) and (11). Fig. 17 shows several polar diagrams for wires of various lengths.

Fig. 18 is a chart showing the angles for which maximum and zero radiation takes place for all lengths of wire up to 14 wavelengths. Figs. 19 and 20 are charts showing the relative amplitudes of the maxima. These charts enable one to plot very quickly in a rough way the radiation characteristic for a wire of any length

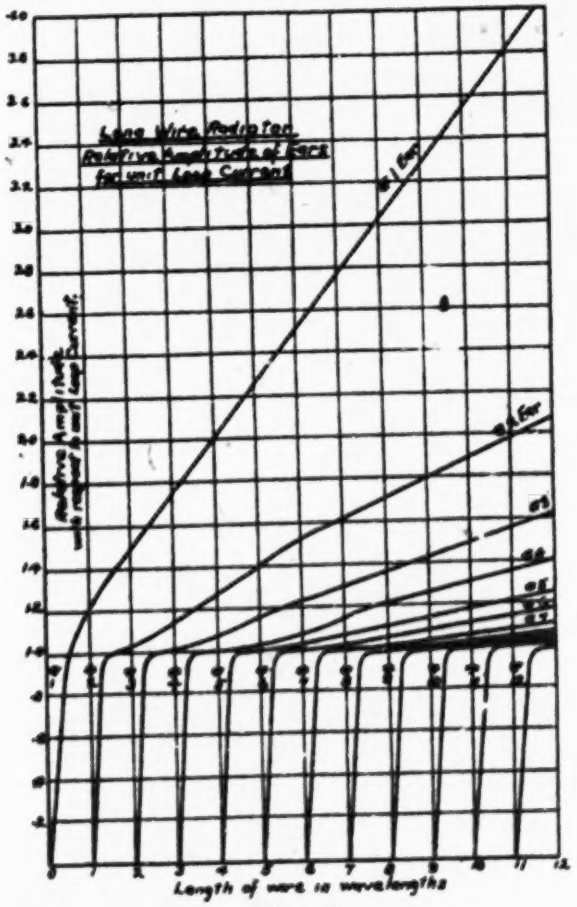


Fig. 19

(*b*) *Radiation Resistance*

The radiation resistance may be defined as the ratio of the total power radiated to the square of the current at a current antinode. All the power radiated must flow through such an imaginary sphere as we have been considering. Therefore, if we divide the surface of the sphere into small areas and sum up the power flowing through all these small areas we shall have the total power.

The power per unit area flowing through the surface of the sphere (Poynting's vector) is

$$P = \frac{c}{4\pi} e^2. \tag{16}$$

Hence, the total power, dW, flowing through a small area dS is:

$$dW = Pds = \frac{c}{4\pi} e^2 ds. \tag{17}$$

Our element of area is:

$$dS = 2\pi r^2 \sin\theta d\theta \tag{18}$$

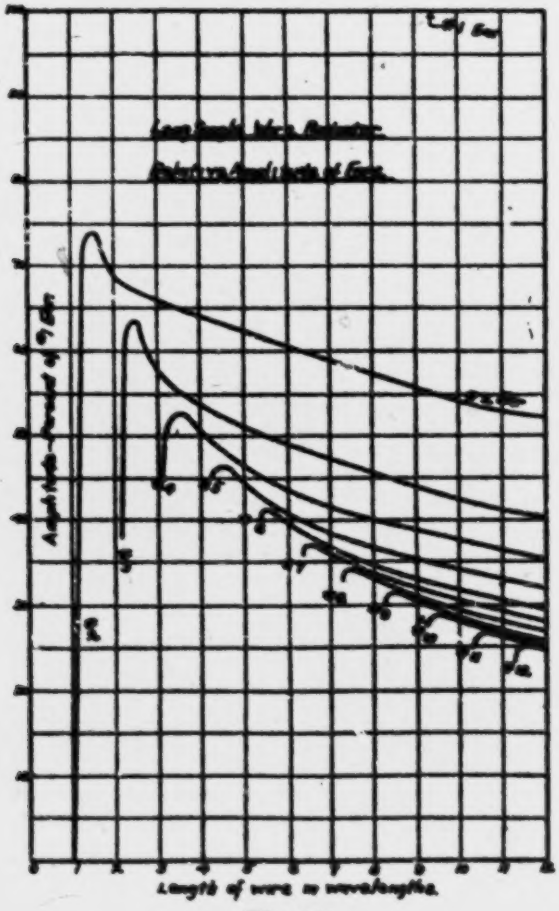


Fig. 20

hence,

$$dW = \frac{ce^2}{2} r^2 \sin\theta d\theta. \tag{19}$$

For the case of an even n we obtain, by substituting the value of e from (10) into (19):

$$dW = \frac{2I^2}{c} \sin^2(\omega t + \beta) \frac{\sin^2\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta} d\theta. \tag{20}$$

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The total power through the whole surface is then:

$$W = \frac{4I^2}{c} \sin^2(\omega t + \beta) \int_0^{\pi/2} \frac{\sin^2\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta} d\theta. \quad (21)$$

To evaluate the above definite integral let $\cos\theta = u$. Then $du = -\sin\theta\, d\theta$ and $\sin\theta = \sqrt{1-u^2}$ and, calling the integral J,

$$J = \int_0^{\pi/2} \frac{\sin^2\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta} d\theta = -\int_1^0 \frac{\sin^2\left(\frac{n\pi}{2}u\right)}{\sqrt{1-u^2}} \frac{du}{\sqrt{1-u^2}}$$

$$= \int_0^1 \frac{\sin^2\left(\frac{n\pi}{2}u\right)}{1-u^2} du = \frac{1}{2}\int_0^1 \frac{1-\cos n\pi u}{1-u^2} du$$

but, since

$$\frac{1}{1-u^2} = \frac{1}{2}\left[\frac{1}{1+u} + \frac{1}{1-u}\right]$$

$$J = \frac{1}{4}\int_0^1 \frac{1-\cos n\pi u}{1+u} du + \frac{1}{4}\int_0^1 \frac{1-\cos n\pi u}{1-u} du$$

$$= \frac{1}{4}\int_0^1 \frac{1-\cos n\pi u}{1+u} du + \frac{1}{4}\int_{-1}^0 \frac{1-\cos n\pi u}{1+u} du$$

$$= \frac{1}{4}\int_{-1}^{+1} \frac{1-\cos n\pi u}{1+u} du.$$

Let $n\pi(u+1) = \phi$ then $n\pi u = \phi - n\pi$ and $du = d\phi/n\pi$, and

$$J = \frac{1}{4}\int_0^{2\pi n} \frac{1-\cos(\phi - n\pi)}{\phi} d\phi$$

$$= \frac{1}{4}\int_0^{2\pi n} \frac{1-\cos\phi}{\phi} d\phi$$

since $\cos(\phi - n\pi) = \cos\phi$, and

$$W = \frac{I^2}{c} \sin^2(\omega t + \beta) \int_0^{2\pi n} \frac{1-\cos\phi}{\phi} d\phi \quad (22)$$

or,

$$W = \frac{I^2}{c} \sin^2(\omega t + \beta)[\log_e 2\pi n + \gamma - Ci(2\pi n)] \quad (23)$$

where, $x = 0.5772 + \cdots =$ Eulers constant, and

$$Ci(2\pi n) = \int_{\infty}^{2\pi n} \frac{\cos\phi}{\phi}\, d\phi.$$

Tables and curves of $Ci\ (x)$ are given in the appendix to Steinmetz' "Transient Electric Phenomena" and Jahnke-Emde's "Functiontafeln mit Formeln und Kurven."

For values of n greater than 2, $Ci\ (2\pi n)$ can be neglected in comparison with $\log_e (2\pi n)$ and

$$W = \frac{I^2}{c} \sin^2 (\omega t + \beta) [\log_e 2\pi n + 0.5772] \tag{24}$$

(approximately) when $n > 2$.

The radiation resistance is then:

$$R = \frac{W}{I^2 \sin^2 (\omega t + \beta)} \tag{25}$$

or,

$$R = \frac{1}{c} [\log_e 2\pi n + 0.5772 - Ci(2\pi n)] \tag{26}$$

in electrostatic cgs units, or,

$$R = \frac{1}{c} \cdot \frac{c^2}{10^9} \cdot [\quad] = 30 [\log_e 2\pi n + 0.5772 - Ci(2\pi n)] \text{ ohms} \tag{27}$$

and,

$$R = 17.23 + 30 \log_e (2\pi n) \text{ ohms.} \tag{28}$$

(approximately) when $n > 2$.

A similar analysis for the case of a wire an odd number of wavelengths long results in formulas identical with those just given. A curve of radiation resistance versus length of radiator is shown in Fig. 21.

(c) *Directivity*

To date there has been no standard quantative definition for directivity. For the present purpose we shall define this term as follows: "Directivity is the ratio of the power per unit solid angle flowing in the direction of maximum radiation to the average power per unit solid angle flowing in all directions from a radiating system." In this discussion we shall define unit solid angle as the solid angle subtended by unit area on a sphere of unit radius. Thus the total solid angle subtended by

any sphere is 4π. On a sphere of radius r the solid angle subtended by an area S is S/r^2.

Poynting's vector, P, has already been defined as the power per unit area flowing through the surface of a sphere. Hence for any sphere of radius r the power per unit solid angle is Pr^2. If P_m is the value of P in the direction of maximum radiation and W the total power radiated,

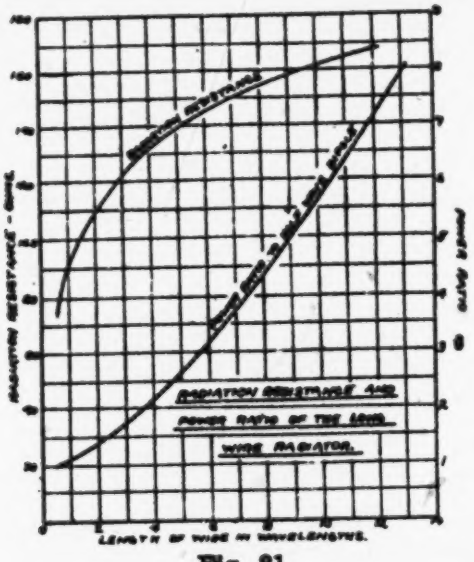


Fig. 21

then the average power per solid radian is $W/4\pi$ and, for the directivity, we have the relation:

$$D = \frac{4\pi r^2 P_m}{W} = \frac{cr^2 e_m^2}{W}. \tag{29}$$

Since the total power W is the surface integral of P over the sphere and $P = c/4\pi e^2$ we obtain:

$$D = \frac{cr^2 e_m^2}{\frac{1}{4\pi}\int\int_S ce^2 dS} = \frac{4\pi r^2 e_m^2}{\int\int_S e^2 dS}. \tag{30}$$

In the general case where the field intensity varies both with latitude and longitude, the element of area on the sphere is:

$$dS = r^2 \sin\theta d\theta d\phi.$$

In the particular case of a linear radiator where the intensity varies with the latitude only, we can take as our element of area a narrow zone for which $dS = 2\pi r^2 \sin\theta d\theta$.

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Thus in the general case:

$$D = \frac{4\pi e_m^2}{\int_0^{2\pi}\int_0^{\pi} e^2 \sin\theta d\theta d\phi} \tag{31}$$

and in the special case of a single linear radiator:

$$D = \frac{4\pi r^2 e_m^2}{2\pi r^2 \cdot 2\int_0^{\pi/2} e^2 \sin\theta d\theta} = \frac{e_m^2}{\int_0^{\pi/2} e^2 \sin\theta d\theta} \tag{32}$$

In practical work we use as a standard for comparing the relative directivity of directional systems the half-wave dipole. By using the value of e from (11) for $\theta = 90$ degrees (the angle of maximum radiation for the half-wave radiator) and the value of W from (23), and then substituting in (32) we obtain:

$$D = \frac{4}{\log_e 2\pi + 0.5772 - Ci(2\pi)} = \frac{4}{2.44} = 1.64 \tag{33}$$

for the half-wave dipole.

Incidentally, the radiation resistance determined by (28) is $30 \times 2.44 = 73.2$ ohms.

In some cases the very short dipole (Hertz doublet) is used as a standard of comparison. Its directivity is 3/2.

From (10) and (28) the directivity of wires an even number of half wavelengths long is:

$$D = \frac{1}{\log_e 2\pi n + 0.5772 - Ci(2\pi n)} \cdot \frac{\sin^2\left(\frac{n\pi}{2}\cos\theta_m\right)}{\sin^2\theta_m} = \frac{120\sin^2\left(\frac{n\pi}{2}\cos\theta_m\right)}{R\sin^2\theta_m} \tag{34}$$

where θ_m is the angle of maximum radiation and R the radiation resistance in ohms.

For wires an odd number of half waves long the directivity is:

$$D = \frac{1}{\log_e 2\pi n + 0.5772 - Ci(2\pi n)} \cdot \frac{\cos^2\left(\frac{n\pi}{2}\cos\theta_m\right)}{\sin^2\theta_m} = \frac{120\cos^2\left(\frac{n\pi}{2}\cos\theta_m\right)}{R\sin^2\theta_m} \tag{35}$$

The power ratio to the half-wave dipole for any directional antenna system is $D/1.64$ or $0.61\ D$. The power ratio to the Hertz doublet is $2/3\ D$.

In Fig. 21 are shown curves of radiation resistance and power ratio to the half-wave dipole plotted as a function of length.

Description of Antenna Models B and C

(a) *General Description*

The antenna Models B and C are made up by combining long linear radiators in such a manner as to obtain a unidirectional characteristic.

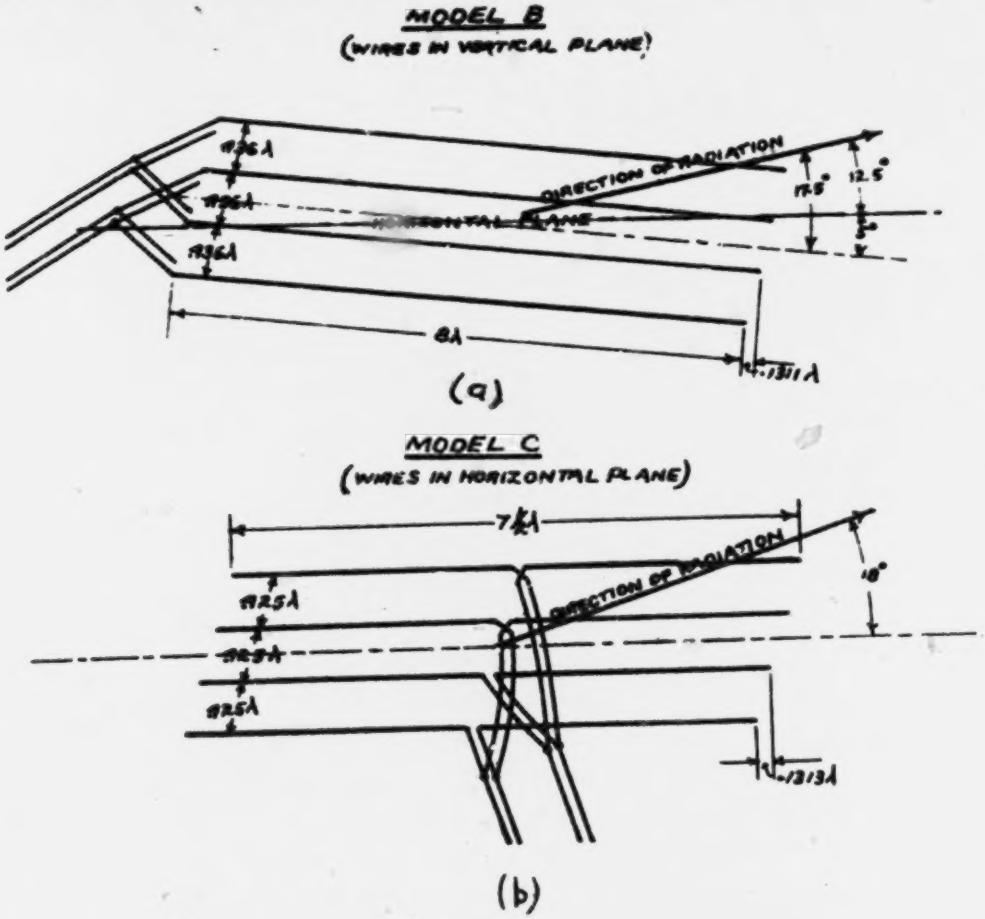


Fig. 22

The two models are very similar. The chief difference between them is that the Model B uses an array of wires in a vertical plane giving vertically polarized radiation whereas the radiators in the Model C are arranged in a horizontal plane and radiate horizontally polarized waves.

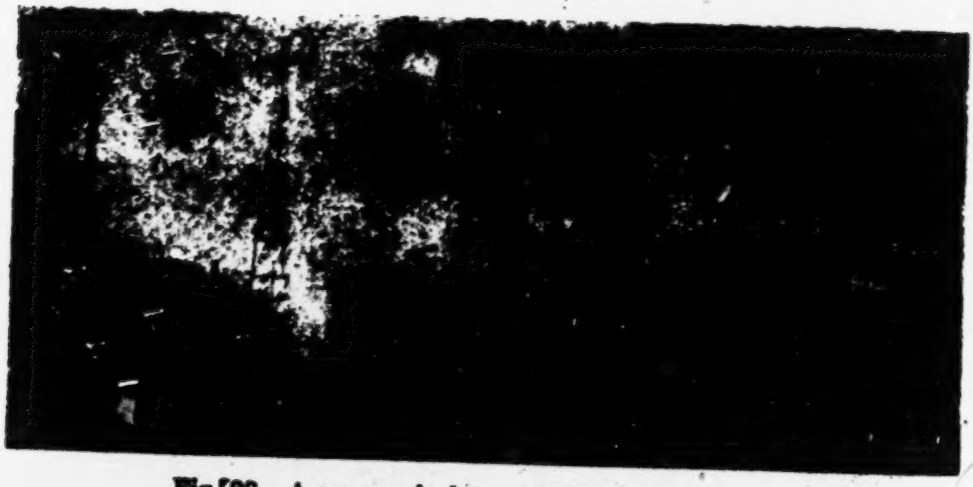


Fig. 23—A commerical type of Model B antenna.



Fig. 24—Feeder details of Model B antenna.

According to the fundamentals of directive antenna technique, a certain concentration or gain of radiation in a special direction calls for

the spreading out over certain physical dimensions of the arrays of individual radiators. Therefore, the simpler the arrangement of these

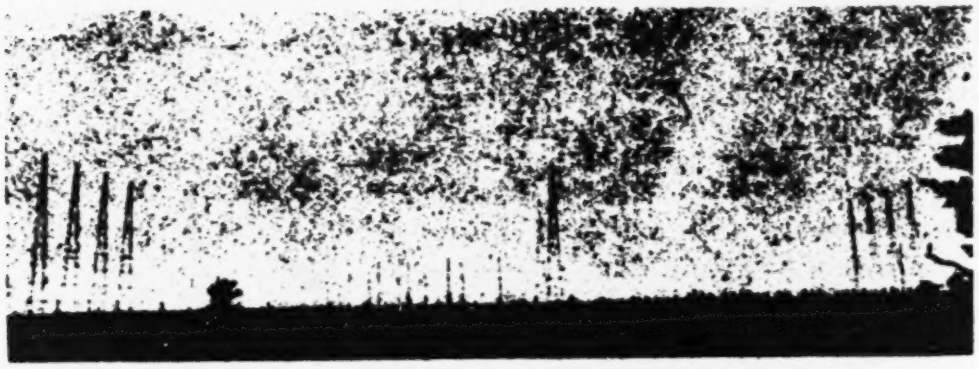


Fig. 25—A commercial type of Model C antenna.

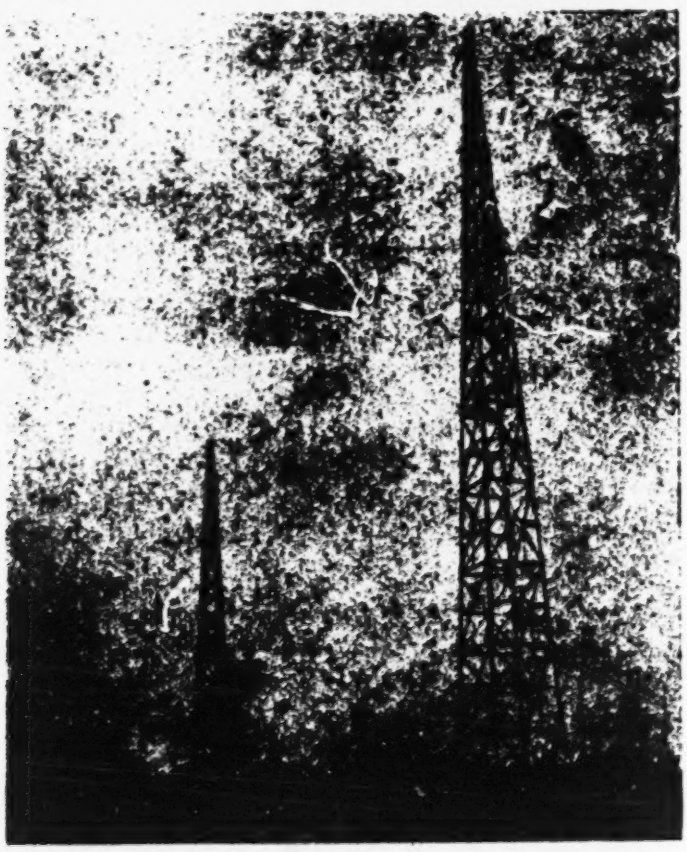


Fig. 26—Feeder details of Model C antenna.

arrays the less expensive will be the structure. The combination of several long linear radiators offers the simplest possible way of doing this. The antenna Models B and C resulted from an effort to obtain the

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best possible combination of these radiators. In these models the wires are all in one plane and so staggered as to obtain a unidirectional characteristic.

One section, or bay, of these antennas consists essentially of four parallel wires, each approximately eight waves long. (See Figs. 22, 23, 24, 25, and 26.)

The vertical antenna, Model B, shown in Figs. 23 and 24, is so constructed that the maximum radiation takes place at an angle of 17.5 degrees upward from the antenna wires but 12.5 degrees upward from the ground.

The horizontal antenna, Model C, shown in Figs. 25 and 26, radiates at an angle of 18 degrees from the longitudinal center line of the antenna. The four wires are arranged in a plane parallel to the ground and at the most economical height. Tests have shown that a minimum

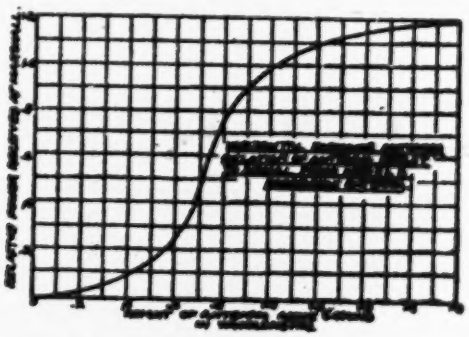


Fig. 27

height of one wavelength should be used, except in case of the longer waves, where the cost of supports is prohibitive. Fig. 27 shows the effect of varying the height above ground of a Model C antenna used on a wavelength of 16.7 meters.

When great directivity is required, several bays are broadsided on the same front at right angles to the direction of transmission and fed cophasially. In connection with the vertical model it was found particularly important to find the optimum spacing between bays. An experimental curve revealed that for two bays this spacing should be about two wavelengths. This was in accordance with the results of theoretical analysis.

It will be noted that the horizontal model may be broadsided either by a parallel arrangement or, in the case of an even number of bays, by reversing the stagger of every other bay, thus letting two adjacent bays form a "*V*." This gives a perfectly symmetrical layout and may, at times, fit in better with the shape of the available ground areas.

A special analysis of the possibilities of using steel towers was carried out.

The features in favor of steel towers are:

1. Saving of space (due to absence of guys)
2. Cleaner design
3. More permanent construction
4. Somewhat lower total cost

Of these points, Nos. 1, 2, and 3 are obvious. A careful detailed study of relative costs bore out point No. 4.

The outstanding objection to the use of steel towers was that they might affect the electrical characteristics of the antenna. It was believed that it should be possible to use steel towers without detrimental effects.

The tests carried out to verify this assumption consisted of imitating a steel tower by surrounding the wooden masts with cables in the form of a skirt.

It was found that the current set up in these cables was too small to be measured by ordinary measuring instruments and that it could be measured only by a tuned circuit indicator (a wave meter). It was attempted to produce particulary bad conditions by adjusting the length of the steel cables so as to tune to the frequency used. There was, however, very little effect obtained. Measurements of signal strength locally as well as at distant points showed the efficiency of the antenna to be unaffected by the presence of the steel cables. On the basis of these experiments steel towers were adopted.

(*b*) *Explanation of Action*

As previously explained, the radiation from a long linear radiator takes place in concentric cones. The radiation from a parallel pair of such radiators carrying currents of opposite phase will cancel in a direction perpendicular to the plane of these radiators. The radiation is then maximum in the plane of the wires and at angles coinciding with the angles of the cone.

With the pair of parallel radiators we get four main lobes of radiation, as shown in Fig. 28, having their maximum intensity in the plane of the wires. The intensity of these lobes in other planes through the axis AA decreases gradually to zero as we approach a plane perpendicular to the plane of the wires.

By staggering the ends of the wires, two of the four lobes are eliminated. This is done by arranging the two wires in the pair so that a line drawn through the ends of the wires forms an angle β with the axis

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A-A, which is the complement of the angle α of maximum radiation with respect to the same axis. (See Fig. 29.)

In the direction B all points on one wire in the pair have a corresponding point on the other wire of opposite phase and on the same wave front in the direction B. Therefore, cancellation takes place in this direction. Cancellation also takes place in the direction opposite to

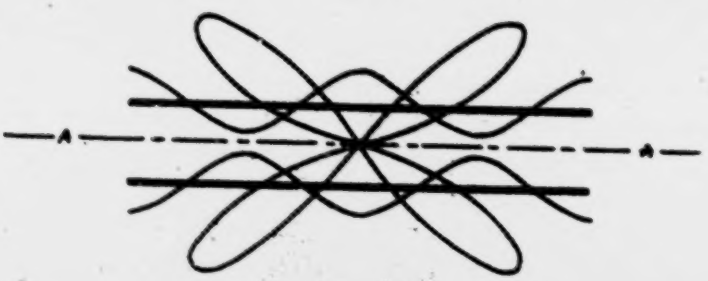


Fig. 28.

B. The combination of two wires in this fashion constitutes the element on which the antenna Models B and C are based. The optimum spacing between the two wires is then the one which makes the radiation from two corresponding points on the pair add perfectly in the direction D of the remaining two lobes. This takes place when the distance $c = \lambda/2$.

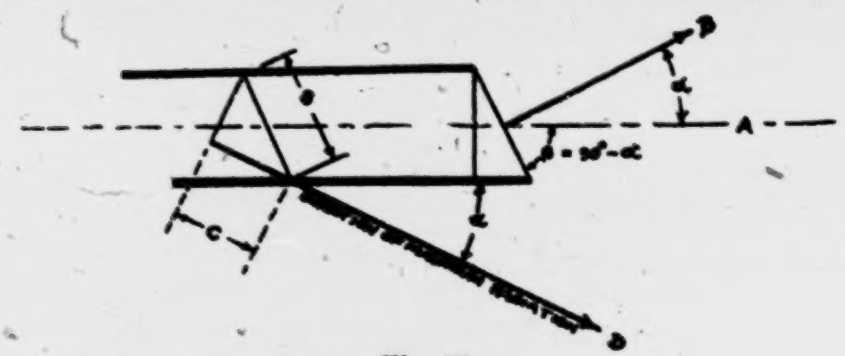


Fig. 29

The back ear is now eliminated by introducing a similar pair of wires at quarter-wave phase and quarter-wave space relation to the first pair. This is illustrated in Fig. 30(A).

The two antenna wires are designated by A and the two reflector wires by R. The pair A is identical with the pair R and both are identical with the pair previously described and shown in Fig. 29. One of the wires R (Fig. 30(A)) is sandwiched halfway between the wires A and the other falls outside one of these wires at an equal distance. The spacing between corresponding points on one reflector wire and its adjacent antenna wire then becomes $c/2$ or $\lambda/4$ in the chosen direction of radia-

tion. If R_1 leads A_1 by a 90-degree phase angle the space difference will cause cancellation of this lead in direction D and the two will add up their radiation in that direction. In the opposite direction the angle of lead is increased from 90 to 180 degrees due to the quarter-wave space difference, and cancellation will take place in that direction. A unidirectional beam is thus obtained.

One of the advantages of this arrangement wherein it differs from broadside methods, is that concentration is obtained both vertically and horizontally. This is a characteristic inherent with all end-on methods.

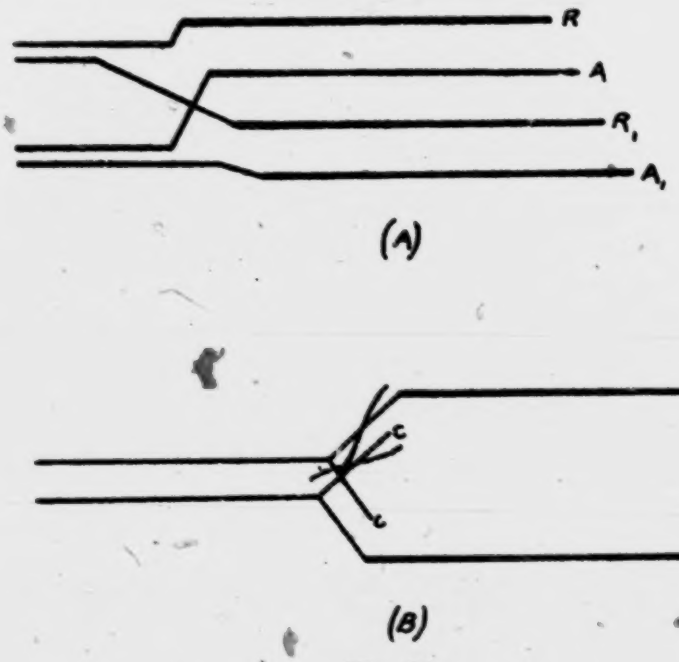


Fig. 30

As the wires in each pair are rather far apart, care must be taken that the connecting leads to the feeding transmission line do not cause unwanted radiation. One way to do this, which is the method used in the Model B antenna, is shown in Fig. 30(B). The length of the wires is so chosen as to produce opposing waves in the canceling sections C.

(c) *Tuning and Impedance Matching Circuits*

A convenient method by which tuning and phasing of the antenna circuits can be conveniently carried out has been developed. The arrangements used are shown in Fig. 31.

The short circuits S_1 and S_2 are so adjusted as to tune the antenna and connecting feed lines. The distance a is adjusted so that the

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impedance at p_1 matches that of the quarter wave long connection between p_1 and p_2. Thus there will be no reflection on this line and it will have only traveling waves. This being the case, it acts as a phase rotator giving a rotation of 90 degrees between p_1 and p_2. The distance b is so adjusted that the antenna and reflector carry equal currents. The distance c is so adjusted that there is no reflection on the line from the transmitter. The short circuit S_3 is always kept one-quarter wavelength from point p_4 to kill end effect.

For the longer waves the dimensions of this form of tuning circuit become inconvenient and the more compact matching devices consisting of lumped inductances and capacities are used.

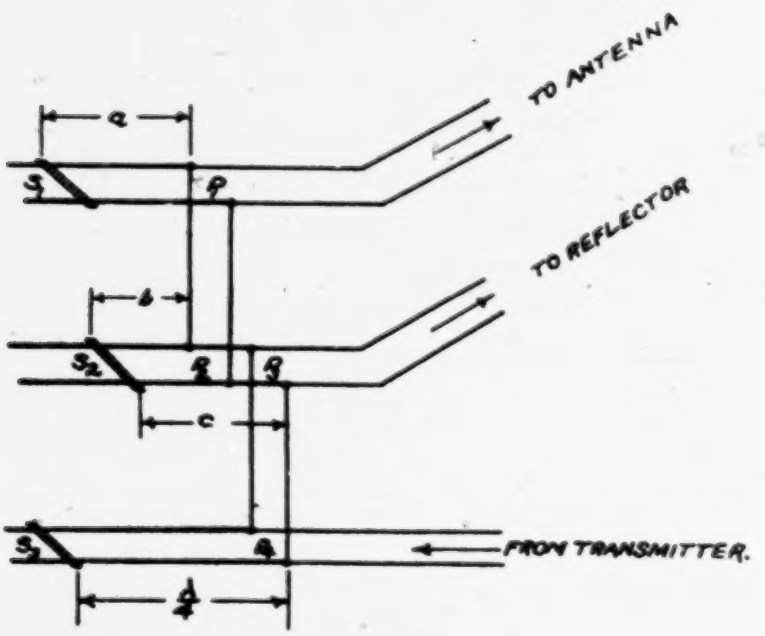


Fig. 31

(*d*) *Directive Characteristics*

Polar diagrams of relative power distribution in one plane show little in regard to the relative merits of antenna systems and are often very misleading. We should know the amount of power flowing in all directions throughout space. If we could place our antenna system at the center of a large sphere and make a survey of the amount of power flowing through each unit area of this sphere, our knowledge would be complete. If, from this data, we were to plot contour lines of equal intensity on a small sphere we should obtain an excellent picture of what takes place. Finding the sphere unhandy for use, we could cut it in half at the equator and project each hemisphere with its contour

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lines and its coördinate lines of latitude and longitude on a plane sheet of paper Such a diagram is, of course, distorted in area but presents a good picture of the distribution of radiation. Figs. 32 and 33 are examples of such diagrams and show the characteristics for one and two bays respectively of the Model B antenna. It will be seen from

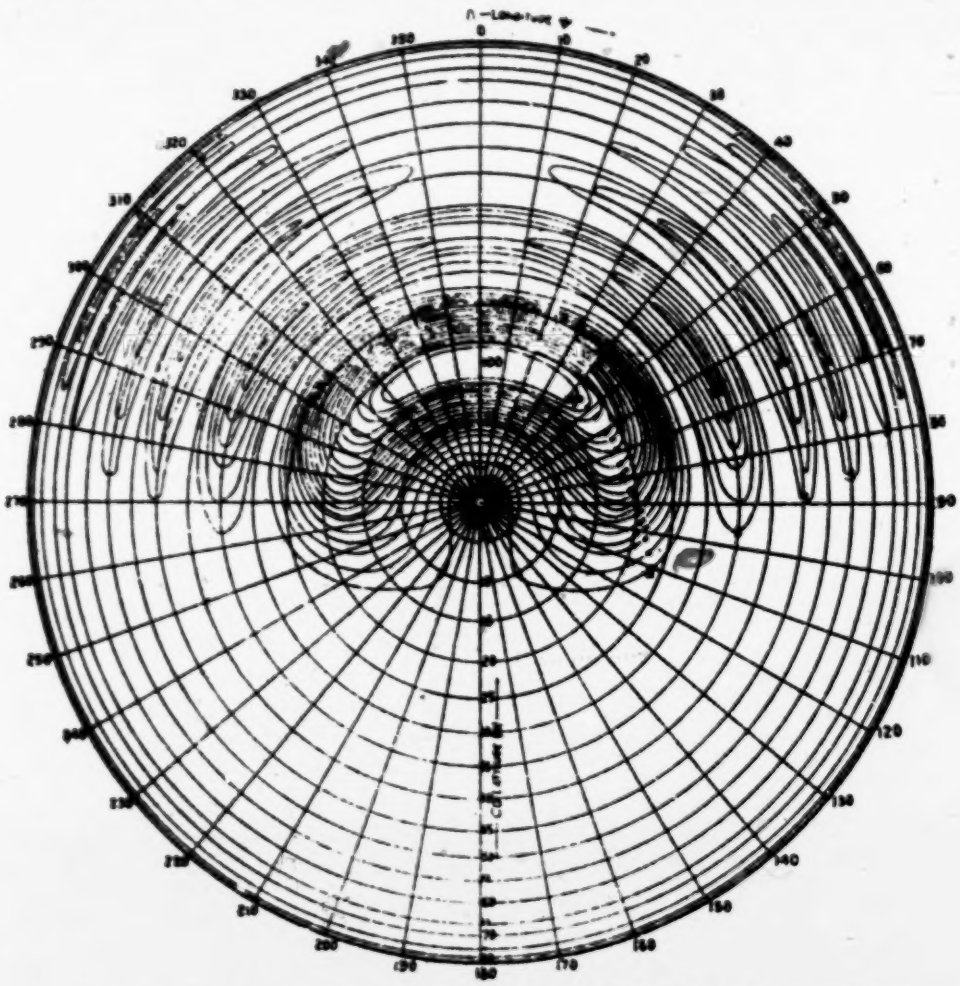


Fig. 32—This map is a projection of front half of imaginary sphere with one-bay vertical harmonic wire projector in the center.

Fig. 33 that the beam from two bays of the Model B antenna is remarkably like that of a search light.

(e) *Method of Calculating Directive Characteristics*

Consider two similar parallel wires spaced in any manner and let S be the line connecting the centers of these wires. (Fig. 34). The field intensity at any point in space is the instantaneous sum of the two components due to the wires. Let the wire pair be at the center of an

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imaginary sphere whose radius is so great that lines from any point P on the surface of the sphere to any points on the radiating wires may be considered parallel. We can then neglect the effect of differences in distance upon the amplitudes and need only consider the phase. Let us take the line midway between the wires as our polar axis and measure

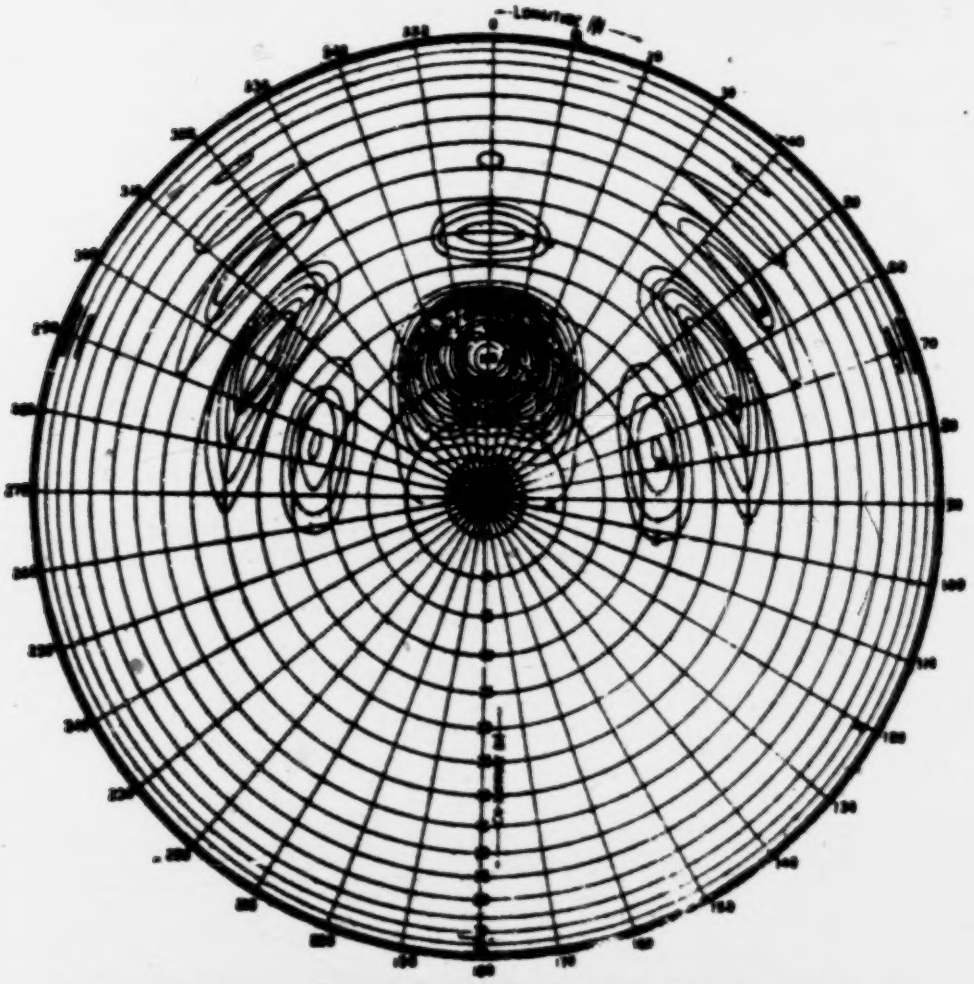


Fig. 33—This map is a projection of front half of imaginary sphere with two-bay vertical harmonic wire projector in the center.

positions of the point P in terms of the colatitude angle θ and the longitude angle ϕ using the intersection of the plane of the wires with the surface of the sphere as the zero meridian.

At a great distance we can consider the field components from the wires as originating at their centers. Now the difference in the distances of travel of the two components is the projection Δd of the line S upon the radius vector r to P. The difference in time of travel, Δt

must then be: $\Delta t = \Delta d/c$ where c is the velocity of light. The corresponding phase angle is then:

$$\gamma = 2\pi f \frac{\Delta d}{c} = 2\pi \frac{\Delta d}{\lambda} \tag{36}$$

where λ is the wavelength, and the wave from b leads the wave from a by this phase angle, provided the currents are in phase in the two wires. Suppose the current in b lags the current in a by the phase angle $\mathcal{E}$. The total phase angle between the two field components is then:

$$\psi = \gamma - \mathcal{E} \tag{37}$$

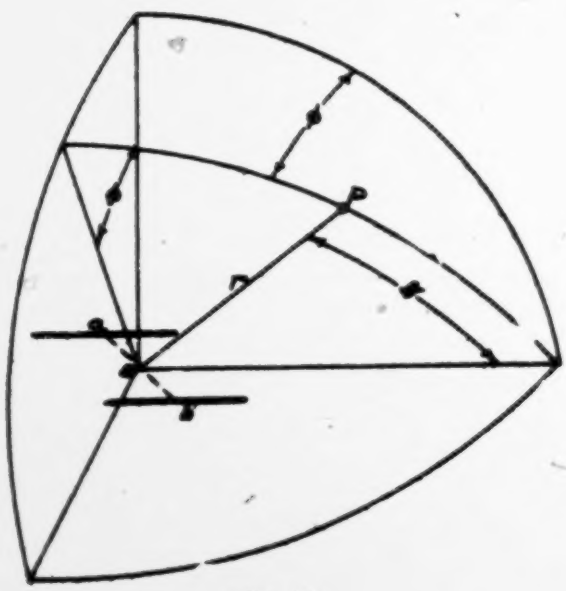


Fig. 34

Let $e_a = E_1 \sin \omega t$ be the field at P due to wire a. Then that due to wire b is $e_b = E_1 \sin(\omega t + \psi)$. Then the total field e_2 due to both is:

$$e_2 = e_a + e_b = 2E_1 \sin\left(\omega t + \frac{\psi}{2}\right) \cos\frac{\psi}{2}. \tag{38}$$

We have already stated that the power P per unit area flowing through the surface of the sphere is $(c/4\pi)e^2$. We are interested in the time average of P which we shall designate as $\bar{P}$ and, to save words, shall simply call it "power." Since the time average of $\sin^2(\omega t + \psi)$ is one-half regardless of the phase angle ψ,

$$\bar{P} = \frac{c}{8\pi} E^2. \tag{39}$$

Hence for the pair:

$$P_2 = \frac{c}{8\pi} 4E_1^2 \cos^2 \frac{\psi_1}{2} \tag{40}$$

$$= 4P_1 \cos^2 \frac{\psi_1}{2} = 2P_1(1 + \cos \psi_1) \tag{41}$$

where P_1 is the power for one wire alone in space.

We can consider this pair as a unit and combine it with a second identical pair, spaced from the first in any desired manner, by the same procedure just outlined. If ψ_2 is the total phase angle between the field components, as determined by the spacing between centers of the pairs and the phase relations of the currents in the wires, the power P_4 for the four is:

$$P_4 = 4P_2 \cos^2 \frac{2\psi}{2} = 16P_1 \cos^2 \frac{\psi_1}{2} \cos^2 \frac{\psi_2}{2}. \tag{42}$$

We can again combine this unit of four wires with a second similar unit spaced in any desired manner. If ψ_3 is the phase angle between the field components due to each of these sets of four wires, we obtain for the total power due to the complete system of eight wires:

$$P_8 = 4P_4 \cos^2 \frac{\psi_3}{2} = 64P_1 \cos^2 \frac{\psi_1}{2} \cos^2 \frac{\psi_2}{2} \cos^2 \frac{\psi_3}{2} \tag{43}$$

We have shown in the discussion of single wires that the power for one wire is:

$$P = \frac{I^2}{r^2 c} \frac{\sin^2\left(\frac{n\pi}{2} \cos \theta\right)}{\sin \theta} \tag{44}$$

when the length is an even multiple of a half wave and

$$P = \frac{I^2}{r^2 c} \frac{\cos^2\left(\frac{n\pi}{2} \cos \theta\right)}{\sin \theta} \tag{45}$$

when the length is an odd multiple of a half wave.

In order to determine the power in any direction (θ, ϕ) it is now only necessary to determine the phase angles in terms of the coordinates (θ, ϕ) for substitution in the above formulas. We shall first consider the pair eight waves long forming the antenna proper. It is apparent from the geometry of the arrangement shown in Fig. 29 that

the length of the spacing line S is, $S=\lambda/2 \sin 35$ degrees $=0.872\lambda$. The line S makes an angle of $(90-17.5)$ degrees or 1.265 radians with the polar axis. Therefore, in the plane of the wires, where $\phi=0$ the projection Δd of the line S on the radius vector r is:

$$\Delta d = S \cos (1.265 - \theta) = 0.872 \cos (1.265 - \theta) \tag{46}$$

but for the general case of any direction (θ, ϕ) the projection is:

$$\begin{aligned}\Delta d &= 0.872[\cos 1.265 \cos\theta + \sin 1.265 \sin\theta \cos\phi]\lambda \\ &= 0.872[0.954 \cos\theta + 0.3005 \sin\theta \cos\phi]\lambda.\end{aligned} \tag{47}$$

Hence the phase angle γ due to the spacing becomes:

$$\gamma = 2\pi \frac{\Delta d}{\lambda} = 2\pi \cdot 0.872[0.954 \cos\theta + 0.3005 \sin\theta \cos\phi] \tag{48}$$

and, since the currents in the two wires are in phase opposition, the total phase angle is:

$$\psi = \pi - 2\pi \cdot 0.872[0.954 \cos\theta + 0.3005 \sin\theta \cos\phi]. \tag{49}$$

The spacing of the reflector pair from the antenna pair is one-half S and along the same line as S, and the two pairs are fed in quarter-phase relation. Therefore, the total phase angle is one-half that for a single pair or:

$$\psi_2 = \frac{\psi_1}{2}.$$

For the case of two sections of Model B antenna spaced apart by a distance x the projection of the spacing line x on the radius vector is:

$$\Delta d = x \sin\theta \sin\phi \tag{50}$$

and since the two sections are fed in phase, the phase angle is:

$$\psi_3 = 2\pi \frac{x}{\lambda} \sin\theta \sin\phi. \tag{51}$$

The complete expression for the power flow in any direction from a two-section vertical model system having a spacing x between sections is:

$$\begin{aligned}P_s = {} & \frac{I^2 \sin^2 (8\pi \cos\theta)}{r^2 c \sin\theta} \cos^2\left[\frac{\pi}{2} - 0.831\pi \cos\theta - 0.262\pi \sin\theta \cos\phi\right] \\ & \cdot \cos^2\left[\frac{\pi}{4} - 0.4155\pi \cos\theta - 0.131\pi \sin\theta \cos\phi\right] \\ & \cdot \cos^2\left[\pi \frac{x}{\lambda} \sin\theta \sin\phi\right].\end{aligned} \tag{52}$$

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According to the definition which has been given the directivity is

$$D = \frac{P_{max}}{\frac{1}{4\pi} \cdot W} \tag{53}$$

where W is the total power radiated. Since all the power radiated must flow through the surface of the imaginary sphere which we have been considering, the total power W must be the surface integral of P over the sphere. Hence,

$$W = \iint_s P dS$$

$$= \int_0^{2\pi} \int_0^{\pi} P r^2 \sin\theta d\theta d\phi \tag{54}$$

since the element of surface dS on the sphere is $dS = r^2 \sin\theta d\theta d\phi$.

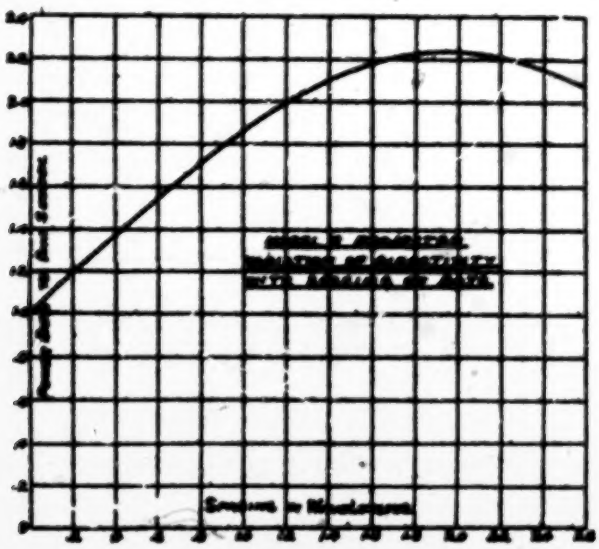


Fig. 35

Due to the extreme complexity of the expression for P (52) this integral cannot be evaluated in terms of elementary functions. Being a double integral mechanical integration involves the plotting of a number of curves. To determine the best spacing for the broadsiding of two sections, it is necessary to repeat the process of evaluation for several values of X. If, by performing one integration, the expression is reduced to a single integral, the labor is greatly reduced, it being necessary to plot only one curve for each condition. This operation has been done with the aid of Bessel's functions.

It can be proved that two sections of any type of radiating system will give an improvement of 2 to 1 in directivity over a single section if they are spaced apart a very great distance. The improvement ratio is an oscillating function of the spacing. It rises from 1 for zero spacing to a value somewhat greater than 2 at some particular spacing, depending upon the characteristics of the single section. As the spacing is further increased the ratio oscillates about a value of 2. For the Model B antenna the first maximum is obtained with a spacing of two wavelengths. Fig. 35 shows the way in which the power varies with the spacing.

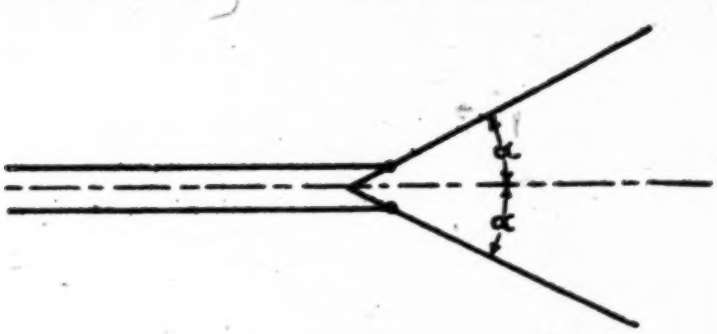


Fig. 36

The theoretical directivity for one section alone was computed as 26.3 and for a two-section system with 2λ spacing as 57.2. The corresponding ratios to a half-wave dipole are 16 and 35.0.

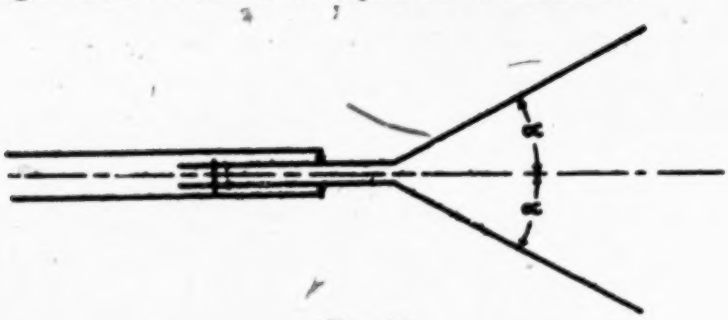


Fig. 37

The Model D Antenna

(a) *Description of System*

The fundamental radiating unit of the Model D antenna is a wire, having a length several times the wavelength used and which is partially folded upon itself from the center as shown in Fig. 36. The energy is fed from a transmission line in a manner similar to that in common use with half-wave dipoles.

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For convenience in making adjustments, the modified arrangement shown in Fig. 37 is actually used. The correct angle (2α) between the wires depends upon their length in terms of wavelength.

Fig. 38 is a schematic diagram of a complete section of this system

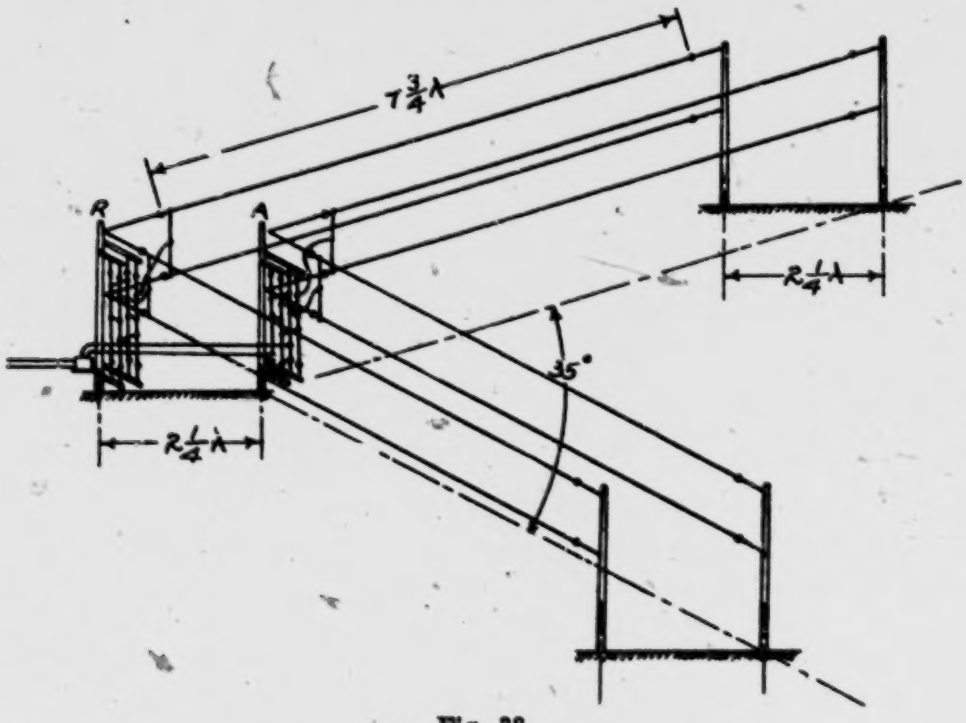


Fig. 38

as used for transmission with wavelengths in the vicinity of 17 meters. One section consists of two pairs of *V* units, *A* and *R*. Each pair consists of two units spaced one above the other at a distance of approxi-

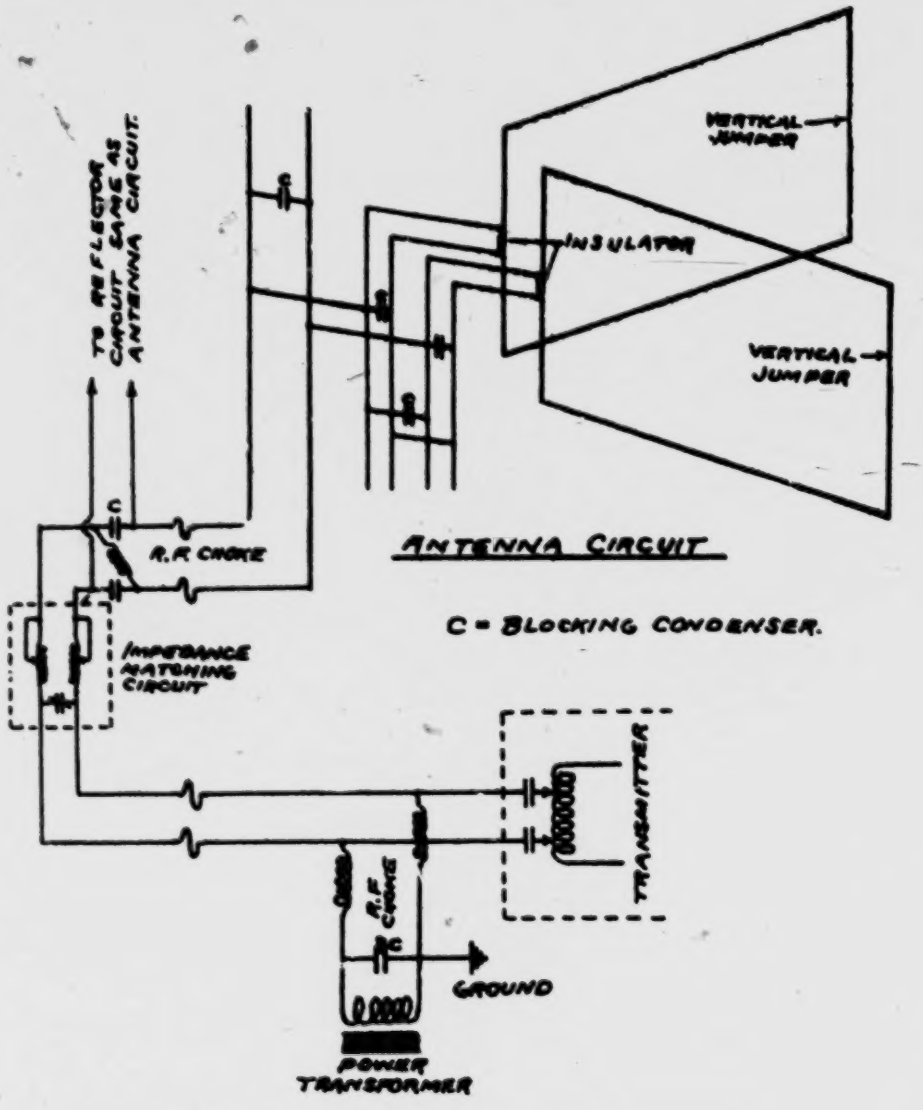


Fig. 39

mately one-half wavelength. The units are fed in phase. The two pairs, *A* and *R*, are separated by a distance of 2 1/4 wavelengths along the center line, and pair *A* is fed in quarter-phase relation, either leading or lagging, with respect to *R*, depending upon whether transmission is to

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be in the direction *A-R* or the direction *R-A*. With the connections as shown in the sketch transmission is in the direction *R-A*. To reverse the direction it is necessary only to make a transposition in the wires of the transmission line between *A* and *R*.



SCHEMATIC DIAGRAM SLEET MELTING CIRCUIT FOR MODEL "D" PROJECTOR

Fig. 40

In Fig. 39 is shown a schematic plan view of a two section system which takes the shape of a *W*. It is seen that a single section requires six supporting structures and each additional section four additional supports.

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This antenna is readily adapted for sleet melting. An arrangement whereby sleet can be melted from both the antenna and its transmission line at one time and without interruption to service is shown in Fig. 40. Radiation from the vertical jumper is negligible due to the fact that the current flow is from both ends toward the center of each jumper.

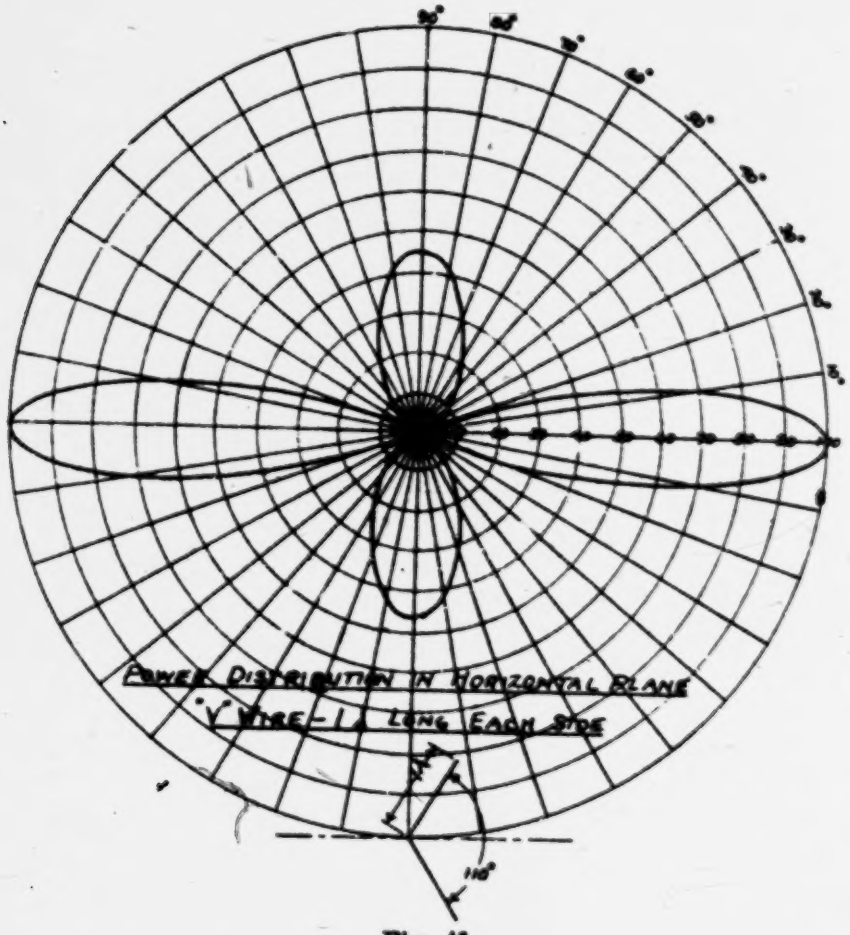


Fig. 41

(*b*) *Explanation of Action*

If a wire, as shown in Fig. 36, has the proper relation between length (in wavelengths) and included angle and is fed in such a manner that the ends are at opposite instantaneous potential, an excellent bidirectional radiating system is obtained. Maximum radiation takes place along the line bisecting the angle. If such a V is connected to a transmission line in the manner already shown in Fig. 37, the correct potential relations will result.

Fig. 41 is a polar diagram showing the power distribution for a V

wire, having sides equal to one wave, in the plane of the wires. Fig. 42 is a similar diagram in a plane at right angles to the plane of the wires, which bisects the angle between them. For the sake of simplicity we shall henceforth call these two planes the horizontal plane and the vertical plane respectively. Figs. 43 and 44 are polar diagrams showing distributions of power for a V wire whose sides are each eight waves long.

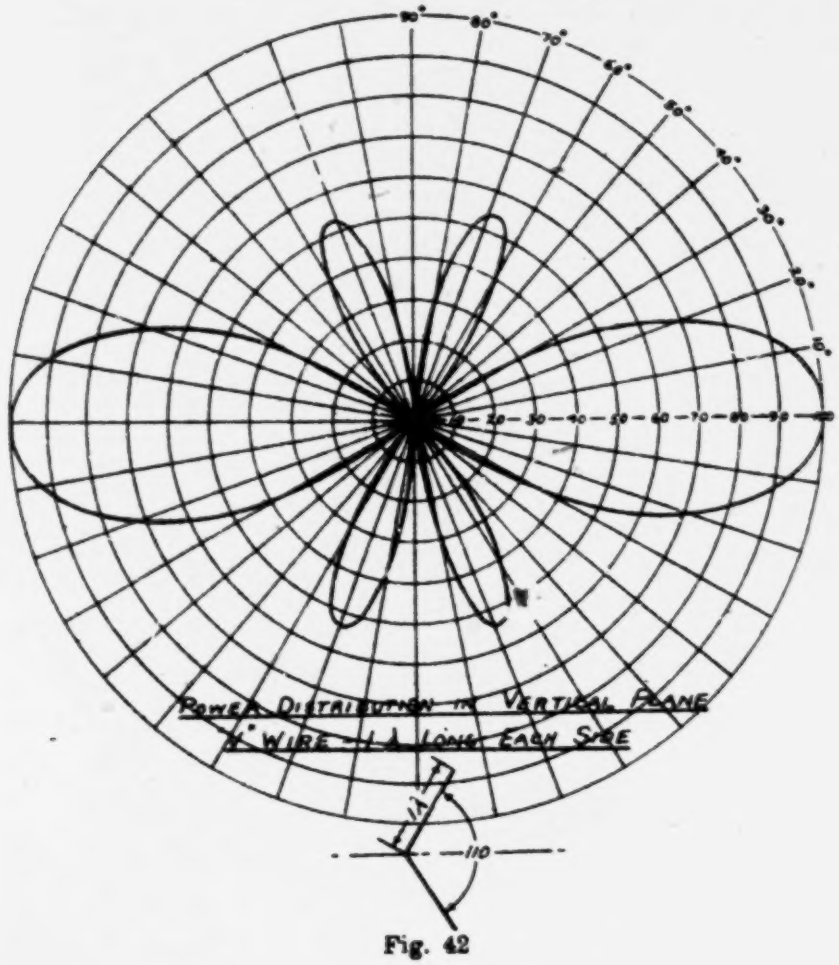


Fig. 42

The power distribution from a V wire can be considered as the effect resulting from the superposition of the radiated field waves from each side of the V. In Fig. 17 were shown a number of polar diagrams of relative power distribution for linear radiators of various lengths. In all cases the direction angle is shown with respect to the wire itself as the axis of reference. If we form a V from two such wires, making the included angle equal to twice the direction angle of the largest lobe, the two component field waves will add in phase along the center line and

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maximum radiation will take place in the two directions along this line. In other directions in the horizontal plane the two components more or less cancel each other by wave interference. In directions at high angles to the horizon we have further reduction in intensities due to the non-parallel directions of the component field vectors. Fig. 45 shows in a qualitative way the manner in which the diagrams for the two wires forming the sides of the V combine to form the resultant pattern.

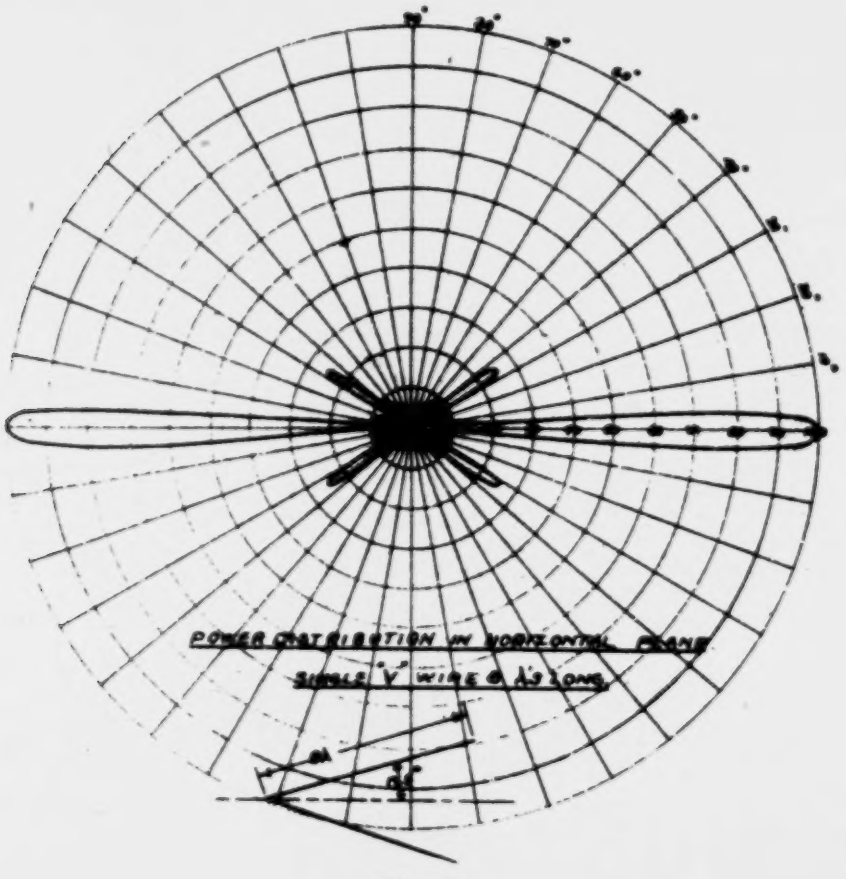


Fig. 43

Fig. 46 is a contour map of the power distribution from a V unit of sides equal to eight wavelengths. This shows only half the directive characteristic. The other half is identical with that shown.

Although the radiation at high angles is too low to show on the contour map, it is distributed over a large portion of the area of the sphere and therefore represents an appreciable portion of the total power. By placing a second V unit above or below the first at a distance of a half wavelength or more, and feeding it cophasially, the high angle radiation is reduced. As previously explained, a unidirec-

tional characteristic is obtained by using two radiator systems in the usual space and phase quadrature relation.

Fig. 47 is a contour map showing the power distribution on an imaginary sphere enclosing a complete antenna section. The antenna is considered as being in space far removed from ground. In the actual case the effect of ground must be considered.

The effect of ground upon a horizontally polarized wave is such as

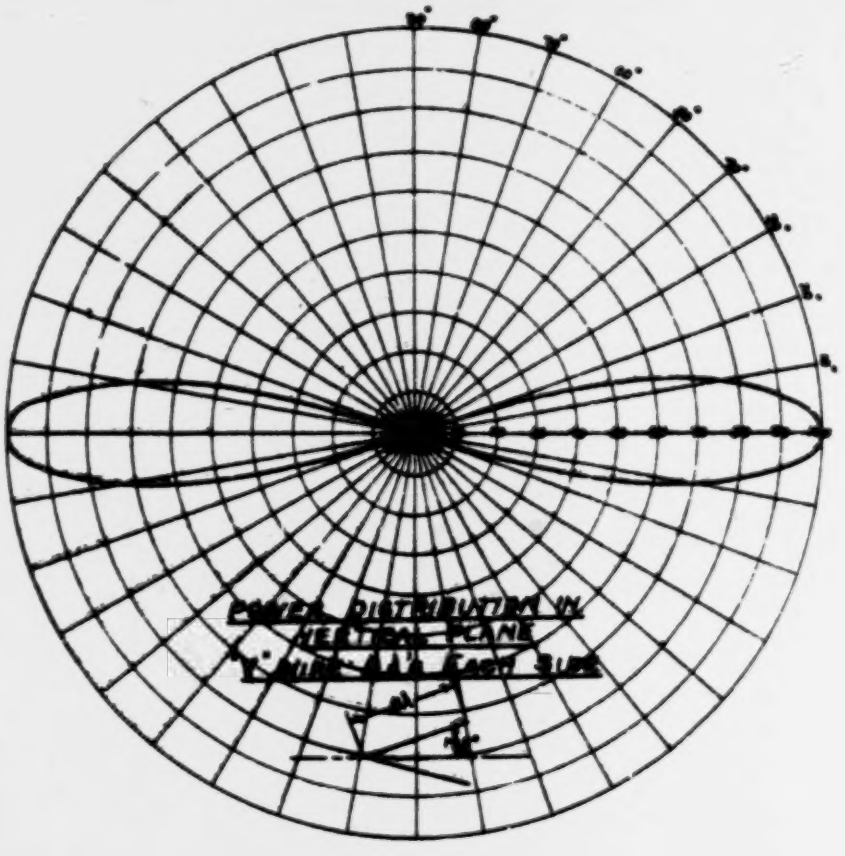


Fig. 44

to cancel radiation at zero angle to the horizon. Fig. 48 is a polar diagram showing the power distribution in the vertical plane when the antenna is located over a perfectly conducting ground and over sandy ground such as at Rocky Point. It is seen that there is little difference in the result in the two cases. The contour map, Fig. 49, shows the power distribution for a one-section antenna located over perfect ground. A comparison of this figure with Fig. 47 shows the effect of ground. Figs. 50 and 51 are contour maps, taking into account the effect of ground for two and three section systems respectively.

(c) Theory

1. The Folded Wire

Before considering the theory of the folded wire radiating system

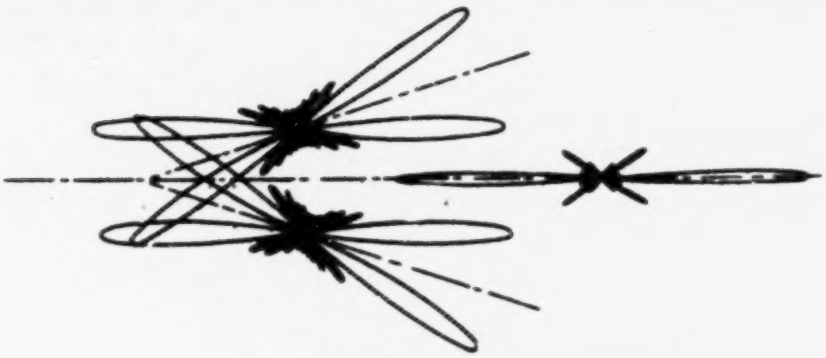


Fig. 45

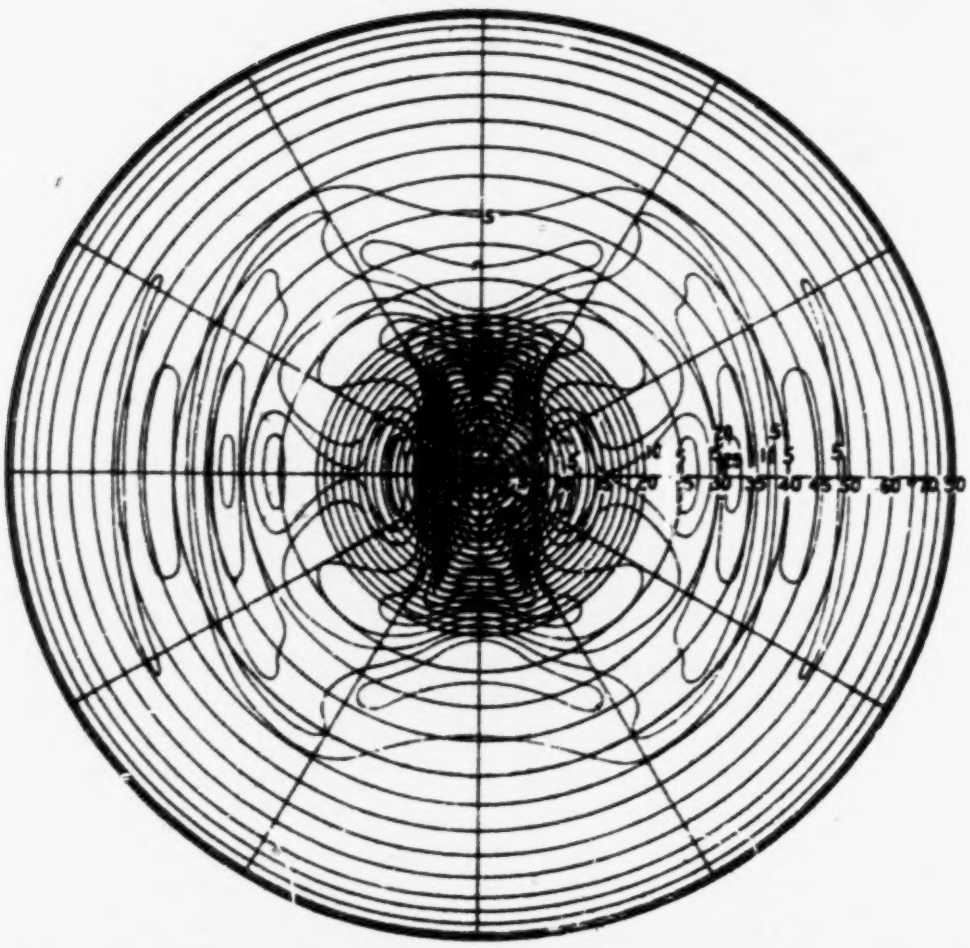


Fig. 46—This map is the projection of a sphere having at its center a single wire eight wavelengths long. Reverse side of sphere identical with frontside.

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we shall discuss certain principles in regard to radiated fields. We have not yet stressed the fact that electric and magnetic field intensities are vector quantities.

At a great distance from a linear radiator the direction of the electric field is at right angles to the radius vector and lies along the meridian line of an imaginary sphere having as its polar axis the axis of the

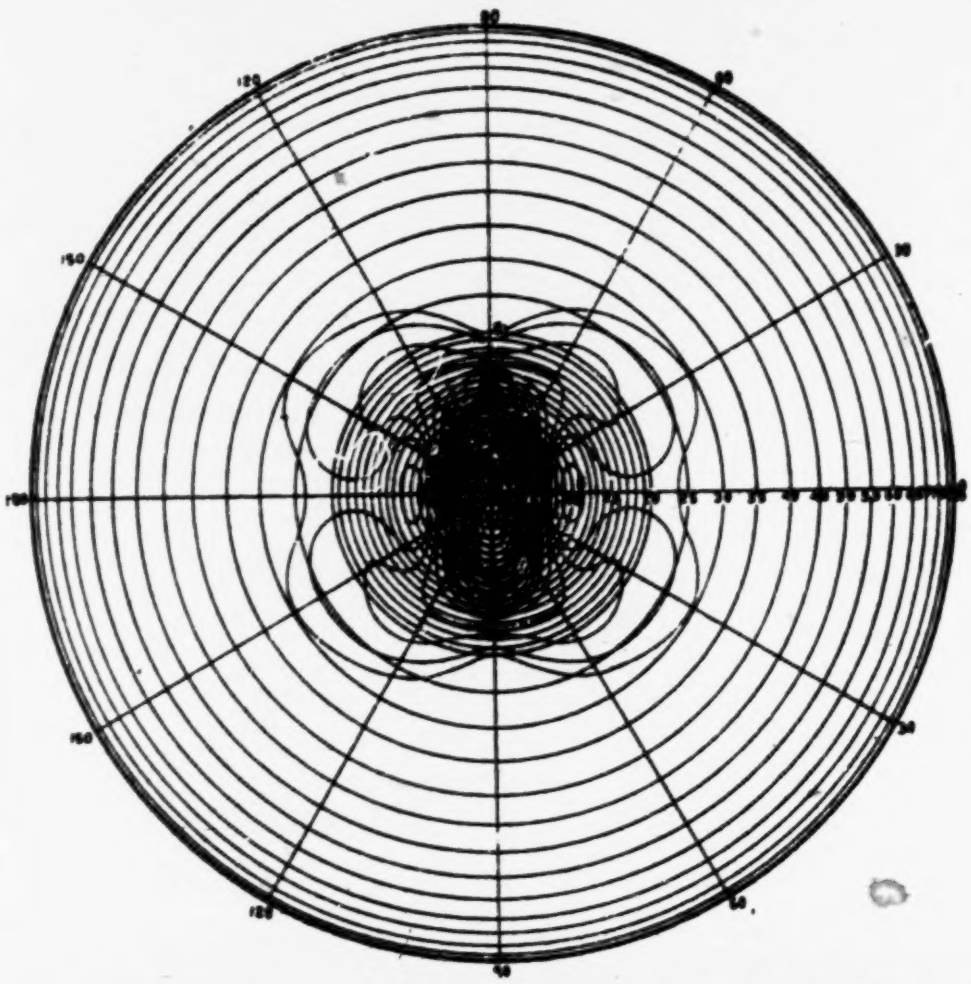


Fig. 47—This map is the projection of a hemisphere having at its center a one bay Model D projector Projector in space, no ground effect considered.

radiator. The direction of the magnetic field is at right angles to that of the electric field and lies along the latitudinal line.

At a great distance from two parallel wires the instantaneous electric intensity vector components are parallel and the resultant instantaneous field is the arithmetical sum of the components. Though the currents in the two radiators may be in phase there is, in general, a phase difference between the component field waves at the point of

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reference due to the difference in time taken to travel the unequal distances to a distant point. Although we may, in this case, obtain the effective value of the resultant field by vectorial addition of the components it should be clearly understood that we are not adding true vectors but are simply making use of the principle that sine waves may be added vectorially. The distinction between a true vector quantity such as electric field intensity and the representation of a sinusoidal function of time, such as a current, by a vector is essential

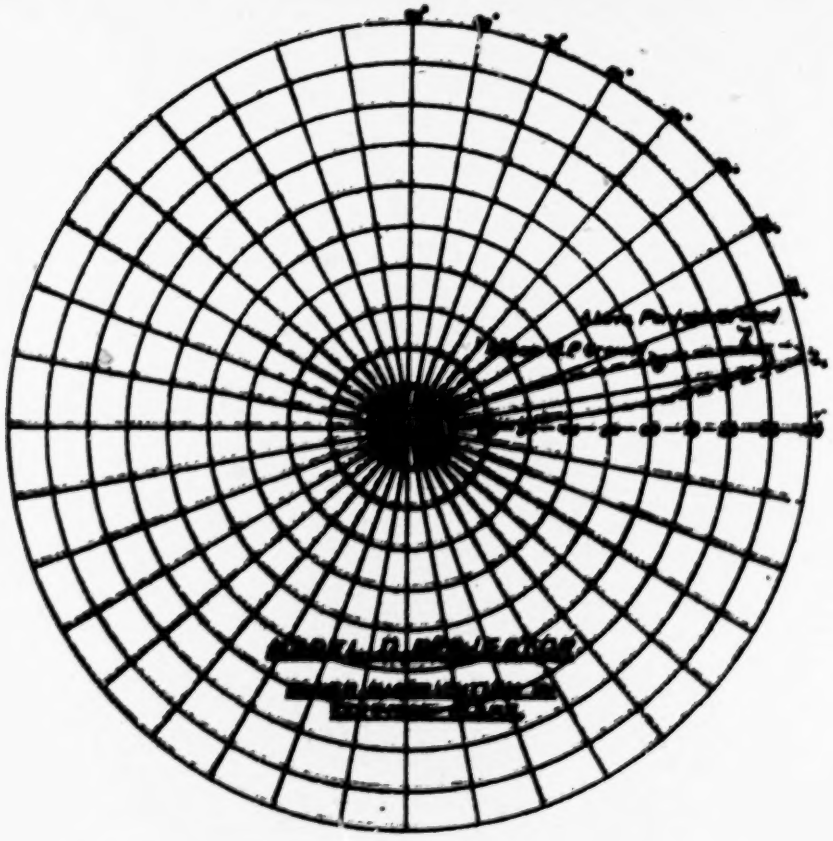


Fig. 48

to a clear understanding of the discussion to follow. The use of vectors to represent sine waves is avoided throughout this discussion in order to reduce the possibility of confusion to a minimum.

In the case where two radiators are not parallel the vector field components are in general not parallel and the resultant field is the instantaneous vector sum. In general the components differ in amplitude, phase, and direction and the terminus of the resultant vector describes an elipse during the period of each cycle. This condition is called elliptical polarization. Circular and plane polarization then be-

come special cases of the more general elliptical polarisation. Fig. 52 is a vector diagram for two sinusoidal vectors having an amplitude ratio of 2:1, differing in phase by an angle of 45 degrees, and in direction by an angle of 60 degrees. Fig. 53 shows the variation of the power for this case.

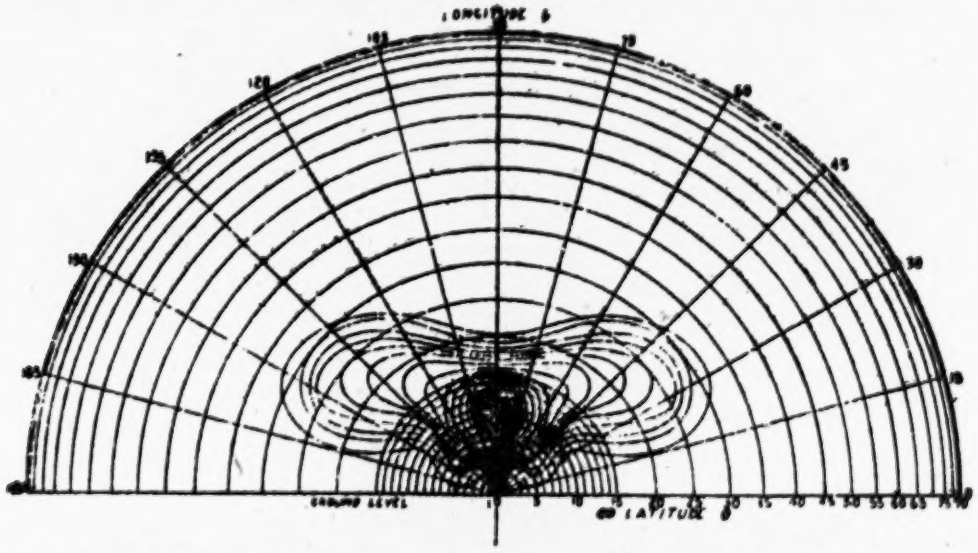


Fig. 49—This map is the projection of the upper front quadrant of an imaginary sphere having at its center a one-bay Model D projector. Projector above perfect ground.

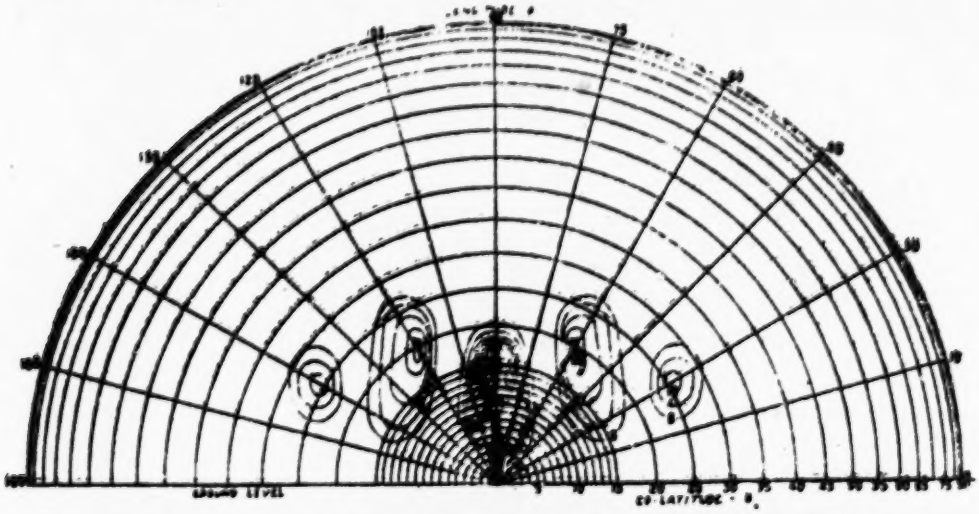


Fig. 50—This map is the projection of an imaginary sphere having at its center a two-bay Model D projector above a perfect ground.

We shall need expressions for the resultant field and the average power for the general case of elliptical polarisation. We shall from now on designate a vector electric intensity by e and the magnitude of e

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by e, the vector amplitude by E and the magnitude of the amplitude by E. It follows that:

$$e = E \sin (\omega t + \beta).$$

Assume that we have an electric intensity e which is the resultant

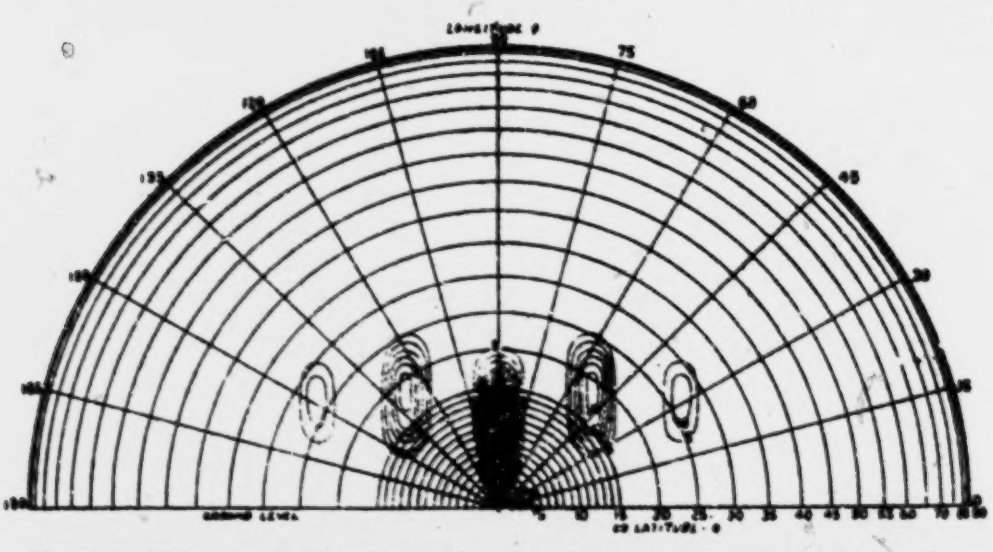


Fig. 51—This map is the projection of an imaginary sphere having at its center a three-bay Model D projector above a perfect ground.

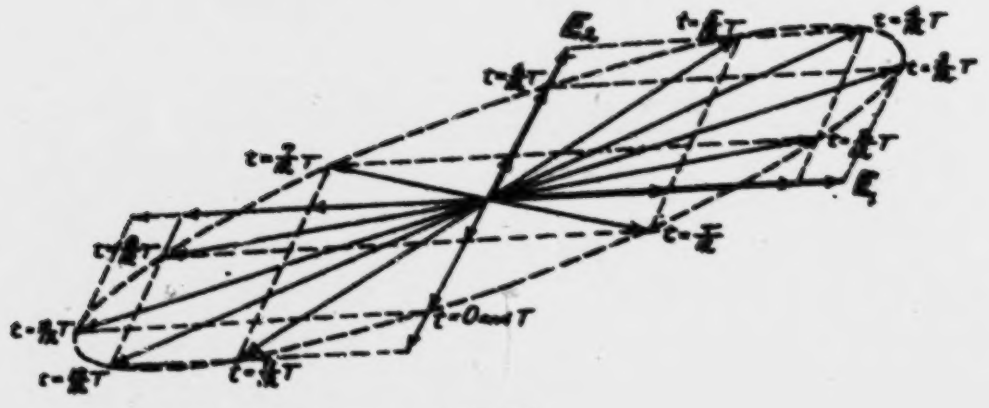


Fig. 52

of two component intensities e_a and e_b. Let these components differ in direction by the angle γ and in phase by the angle ψ. Then:

$$e_a = E_a \sin \omega t \text{ and } e_b = E_b \sin [\omega t + \psi] \tag{55}$$

and,

$$e = e_a + e_b = E_a \sin \omega t + E_b \sin [\omega t + \psi]. \tag{56}$$

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For the magnitude of the resultant intensity we obtain, by solving the vector triangle:

$$e = \sqrt{e_a^2 + e_b^2 + 2e_a e_b \cos\gamma}$$
$$= \sqrt{E_a^2 \sin^2 \omega t + E_b^2 \sin^2(\omega t+\psi) + 2E_a E_b \sin \omega t \sin(\omega t+\psi) \cos\gamma} \quad (57)$$

The power per unit area (Poynting's vector) becomes:

$$P = \frac{c}{4\pi} e^2 = \frac{c}{4\pi}[E_a^2 \sin^2 \omega t + E_b^2 \sin^2(\omega t + \psi) + 2E_a E_b \sin \omega t \sin(\omega t + \psi) \cos\gamma] \quad (58)$$

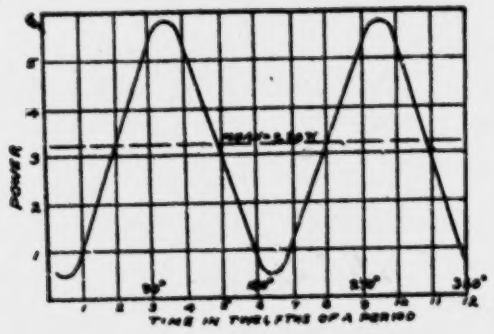


Fig. 53

and the time average of the power per unit area becomes:

$$\bar{P} = \frac{1}{2\pi}\int_0^{2\pi} P d(\omega t) = \frac{c}{8\pi}(E_a^2 + E_b^2 + 2E_a E_b \cos\gamma \cos\psi). \quad (59)$$



Fig. 54

We shall now discuss the field distribution for a single partially folded wire in the plane of the wires. For convenience let us call this the horizontal plane.

At a point P in this plane, whose distance is so great, compared with the dimensions of the radiating V, that all lines from points of the V to P can be considered parallel, the directions of the electric components are parallel and the resultant field is, at any instant, the arithmetical sum of the components. The phase of the total field from

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either wire is the same as the phase of the field from a small element at the center of the wire. Therefore, we may consider the resultant field at P to be due to the fields e_a and e_b from each wire originating at the center points a and b. In Fig. 54 let us take as reference time the time at which a wave from O arrives at P. The wave from a will take Δt seconds longer and the wave from b Δt seconds less than a wave from O where $\Delta t = \Delta d/c$. From the geometry of the figure:

$$\Delta d = \frac{l}{2} \sin \alpha \sin \theta \tag{60}$$

where l is the length of the wire.

To save space we shall consider only the case where the sides of the V are an even number of half waves long.

From (10) we obtain for the two field components, after substituting $t+\Delta t$ and $t-\Delta t$ to take care of the differences in the time of travel to P:

$$e_a = \frac{2I \sin\left(\frac{n\pi}{2} \cos \theta_a\right)}{cr \sin \theta_a} \sin \omega(t - \Delta t) = E_a \sin \omega(t - \Delta t) \tag{61}$$

$$e_b = \frac{2I \sin\left(\frac{n\pi}{2} \cos \theta_b\right)}{cr_b \sin \theta_a} \sin \omega(t + \Delta t) = E_b \sin \omega(t + \Delta t) \tag{62}$$

in which $\theta_a = \theta - \alpha$, $\theta_b = \theta + \alpha$, and $\Delta t = l/2c \sin \alpha \cos \theta$.

Since the currents in a and b are in opposite phase

$$e = e_a - e_b = \sqrt{E_a^2 + E_b^2 - 2E_aE_b \cos\left(2\pi \frac{l}{\lambda} \sin \alpha \sin \theta\right)} \sin(\omega t + \beta) \tag{63}$$

and the time average of the power per unit area becomes:

$$\bar{P} = \frac{c}{8\pi}\left[E_a^2 + E_b^2 - 2E_aE_b \cos\left(2\pi \frac{l}{\lambda} \sin \alpha \sin \theta\right)\right] \tag{64}$$

from which the relative values of the power distribution in the horizontal plane may be computed.

Throughout the remainder of this discussion we shall use the word "power" to indicate the time average of the power per unit area and designate this by $\bar{P}$.

In the plane at right angles to the plane of the wires and including the bisector, which, for convenience, is designated as the vertical plane, the distances to each wire are equal and the time difference of travel zero. However, in this plane, in proceeding from the horizontal to the vertical direction the angle between the directions of the component vectors changes from zero to $(\pi - 2\alpha)$. The two electric field vectors are equal and lie along the meridian lines of two concentric spheres, one having as its polar axis the axis of the wire a and the other the axis of wire b as shown in Fig. 55. If θ is the direction angle to the point P with reference to the bisector and θ_a and θ_b the angles to the wire axes, then

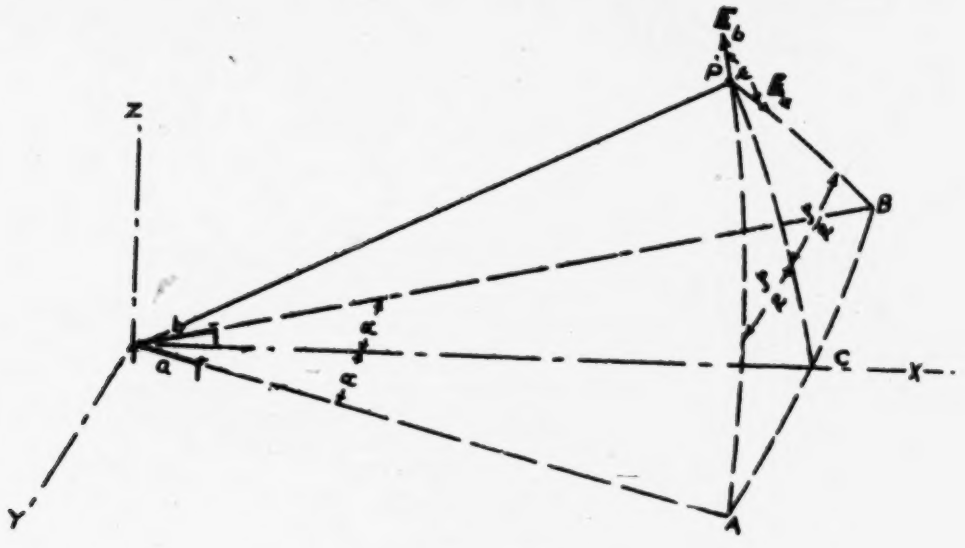


Fig. 55

$\theta_a = \theta_b$. θ_a and ζ are obtained by solving the right spherical triangle $A\,C\,P$, resulting in the relations

$$\cos\theta_a = \cos\theta\cos\alpha \tag{65}$$

$$\sin\frac{p}{2} = \frac{\sin\alpha}{\sin\vartheta_a} = \frac{\sin\alpha}{\sqrt{1-\cos^2\theta\cos^2\alpha}}. \tag{66}$$

The resultant intensity must be the vector sum of the components:

$$e = e_a + e_b$$

but,

$$e_a = e_b$$

therefore,

$$e = 2e_a\cos\frac{\gamma}{2} \tag{67}$$

where γ is the angle between the directions. However, since the wires are at opposite polarity, the angle

$$\gamma = \pi - \zeta \tag{68}$$

where ζ is the angle between the two meridians.
Hence,

$$e = 2e_\theta \sin \frac{\zeta}{2}$$

$$= \frac{4I}{cr} \sin \omega t \frac{\sin\left(\frac{n\pi}{2} \cos \frac{\theta_0}{2}\right)}{\sin \theta_0} \sin \frac{\zeta}{2} \tag{69}$$

upon obtaining the value of e_θ from (10).

Substituting (65) and (66) into (69) we obtain:

$$e = \frac{4}{cr} I \sin \omega t \frac{\sin\left(\frac{n\pi}{2} \cos \alpha \cos \theta\right) \sin \alpha}{1 - \cos^2 \theta \cos^2 \alpha} \tag{70}$$

and the time average of the power is

$$P \sim \left|\frac{c}{4\pi} e^2\right|_{ave} = \frac{2I^2 \sin^2\left(\frac{n\pi}{2} \cos \alpha \,.\, \cos \theta\right)}{\pi c r [1 - \cos^2 \theta \cos^2 \alpha]^2} \tag{71}$$

or,

$$P \propto \frac{\sin^2\left(\frac{n\pi}{2} \cos \alpha \,.\, \cos \theta\right)}{[1 - \cos^2 \theta \cos^2 \alpha]^2} \tag{72}$$

and from this proportionality can be calculated the relative power distribution in the vertical plane. The power distribution for V wires having sides one wave and eight waves long respectively have already been shown in Figs. 42 and 44.

In planes other than the two already considered, the field vector components differ in amplitude, direction and phase. We have already shown how this results in elliptical polarization and derived the formula for the power. In order to make use of the formula we must first determine the phase angle and the direction angle between the two vector components.

The phase angle between the wave from a and the wave from b is: $\psi = \omega \Delta t = \omega \Delta d/c$ where Δd is the projection of the line s, connecting the centers of the wires, upon the radius vector r. In spherical coördinates, (see Fig. 56.)

$$\Delta d = s \sin\theta \cos\phi \tag{73}$$

but,

$$s = l \sin\alpha$$

therefore,

$$\psi = 2\pi \frac{l}{\lambda} \sin\alpha \sin\theta \cos\phi. \tag{74}$$

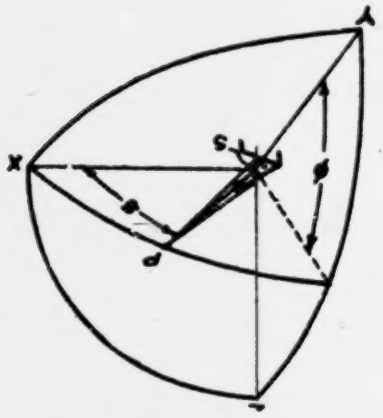


Fig. 56

The vector field components lie along the meridian lines of two superimposed spheres having as their polar axes continuations of the wires as shown in Fig. 57. The angle γ between the vectors is $\pi - \zeta$

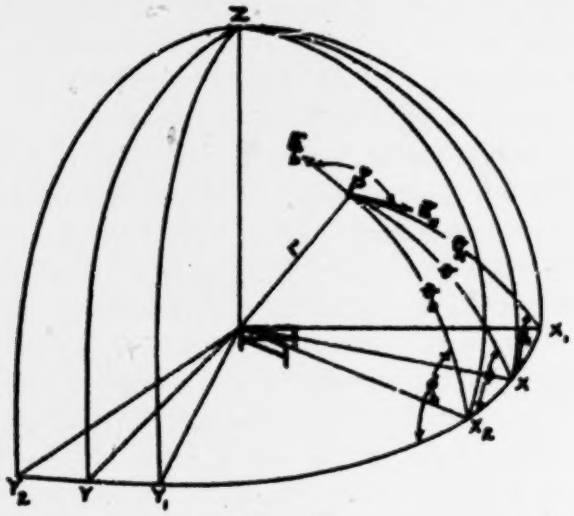


Fig. 57

where ζ is the angle between the meridians. To determine ζ in terms of the coördinates (θ, ϕ) it is necessary to solve the oblique spherical triangle X_1PX_2. We also need θ_a and θ_b in terms of θ and ϕ in order to determine the amplitudes of e_a and e_b.

788 601

By spherical trigonometry:

$$\cos\theta_a = \cos\theta\cos\alpha + \sin\theta\sin\alpha\cos\phi \tag{75}$$

$$\cos\theta_b = \cos\theta\cos\alpha - \sin\theta\sin\alpha\cos\phi \tag{76}$$

and,

$$\cos\frac{\zeta}{2} = \sqrt{\frac{\sin\left(\frac{\theta_a}{2}+\frac{\theta_b}{2}-\alpha\right)\sin\left(\frac{\theta_a}{2}+\frac{\theta_b}{2}+\alpha\right)}{\sin\theta_a\sin\theta_b}}. \tag{77}$$

Upon the substitution of $\pi-\zeta$ for γ in (64) we obtain:

$$\bar{P} = \frac{c}{8\pi}(E_a^2 + E_b^2 - 2E_aE_b\cos\zeta\cos\psi). \tag{78}$$

Having obtained θ_a and θ_b from (75) and (76) we can obtain E_a and E_b from (10), ψ from (74), and ζ from (77) which, upon substitution in (78), give us the power radiated in any direction (θ,ϕ). The contour map resulting from such calculations has been shown in Fig. 46.

2. The Complete Antenna Section

If we space two like linear radiators in any manner whatsoever, as long as their axes remain parallel, the field intensity at any point in space is $2e_1\cos\psi/2$ where ψ is the phase angle determined in the proper manner and e_1 the intensity due to one radiator alone. If $\bar{P}_1$ is the power due to one alone, the power due to both is $4\bar{P}_1\cos^2\psi/2$. We can combine any number of pairs of groups according to this law. In the system under discussion we have units resulting in elliptical polarization and we wish to investigate the laws for arrays of such units.

The intensity in an elliptically polarized wave can always be resolved into two harmonic components, one acting along the major axis and one along the minor. A similar case in mechanics is the motion of a pendulum when describing an elliptic orbit. Suppose we have two identical radiating systems in which flow equal currents and which are spaced in any manner whatever as long as the corresponding elements in the two systems remain parallel. Assume that at a point P at a great distance from the two systems we find the phase angle to be ψ, after taking proper account of time of travel and relative phase of currents. Let e_a be the intensity due to either system alone. Let its major and minor components be e_a' and e_a'', respectively, and E_a' and E_a'' the amplitudes of these components. The total field amplitude E' along the major axis is then:

$$E_s' = 2E_s' \cos\frac{\psi}{2} \tag{79}$$

and the total field amplitude E'' along the minor axis is:

$$E'' = 2E_s'' \cos\frac{\psi}{2} \tag{80}$$

The power due to the intensity along the major axis is:

$$P' = \frac{c}{8\pi} 4E'^2 \cos^2\frac{\psi}{2} \tag{81}$$

and for the minor axis:

$$P'' = \frac{c}{8\pi} 4E''^2 \cos^2\frac{\psi}{2} \tag{82}$$

and the total power is:

$$P = P' + P'' = \frac{c}{8\pi} 4(E_s'^2 + E_s''^2) \cos\frac{\psi}{2} \tag{83}$$

but the power due to either system alone is

$$P_s = \frac{c}{8\pi}(E_s^2 + E_s''^2) = \frac{c}{8\pi} E_s^2. \tag{84}$$

Therefore, by substitution the total power is

$$P = 4P_s \cos^2\frac{\psi}{2} \tag{85}$$

which is the same as if the two systems were radiating plane polarised waves. Therefore we can treat arrays of units radiating elliptically polarised waves in the same manner as arrays of simple oscillators.

If we place two identical radiating systems one above the other with a spacing s the phase angle between the two component field waves will be zero for directions in the horizontal plane ($\phi = 0$). At a point in any particular direction (θ, ϕ) in space the phase angle ψ between the components must be: $\psi = 2\pi\Delta d/\lambda$ where Δd is the projection of the vertical line s on the radius vector to the point P. In terms of the spherical coördinates θ, ϕ,

$$\Delta d = S \sin\theta \sin\phi. \tag{86}$$

If P_1 is the power for one system alone then the power for the combination is:

$$P_2 = 4P_1 \cos^2\left(\frac{\pi S}{\lambda} \sin\theta \sin\phi\right) \tag{87}$$

from (85).

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To obtain a unidirectional system we place a second pair (b) of V wires behind the first pair (a) a distance q equal to an odd number of quarter waves and feed system (b) leading (a) in phase by an angle $2\pi q/\lambda$. At a point P in any direction θ, ϕ, in space the difference in time of travel of the waves from a and b is $\Delta d/c$ where Δd is the projection of the horizontal line q upon the radius vector to P. Hence $\Delta d = q \cos\theta$ and the corresponding phase angle is $2\pi q/\lambda \cos\theta$. The total phase angle ψ is the difference between the phase angle due to the currents and the phase angle due to difference in time of travel. Hence

$$\psi = 2\pi \frac{q}{\lambda}(1 - \cos\theta) = \frac{4\pi q}{\lambda} \sin^2 \frac{\theta}{2}. \tag{88}$$

Upon substituting this value of the phase angle in (85) we obtain:

$$P_{ab} = 4P_a \cos^2\left(2\pi \frac{q}{\lambda} \sin^2 \frac{\theta}{2}\right) \tag{89}$$

which becomes, after replacing P_a with its value in terms of P_1 from (85):

$$P_{ab} = 16P_1 \cos^2\left(\frac{\pi S}{\lambda} \sin\theta \sin\phi\right) \cos^2\left(2\pi \frac{q}{\lambda} \sin^2 \frac{\theta}{2}\right). \tag{90}$$

Knowing the value of P_1 for the single V this equation enables us to determine the distribution through space for the complete antenna section. The resulting contour map has been shown in Fig. 47

So far we have considered the antenna system in space only, neglecting any effects due to ground. In most treatments of radiating systems the ground is assumed a perfect conductor in which case it acts as a perfect mirror. In most cases this assumption is not justified. For short wavelengths the ground acts much more like a perfect dielectric than a perfect conductor. At Rocky Point the soil is sand of extremely small conductivity and having a dielectric constant of approximately 9. In this case the conductivity may be neglected in determining the reflection.

It can be shown from electromagnetic theory that the coefficient of reflection for a wave polarized at right angles to the plane of incidence (horizontal polarization) is, for a pure dielectric, given by the formula:

$$K_h = \frac{\cos\delta - \sqrt{\epsilon - \sin^2\delta}}{\cos\delta + \sqrt{\epsilon - \sin^2\delta}} \tag{91}$$

where ϵ is the dielectric constant and δ the angle of incidence. $\delta = 90$ degrees $- \theta$ where θ is the angle to the horizontal.

When a wave is polarized in the plane of incidence the coefficient of reflection is:

$$K_1 = \frac{\epsilon \cos \delta - \sqrt{\epsilon - \sin^2 \delta}}{\epsilon \cos \delta + \sqrt{\epsilon - \sin^2 \delta}}. \tag{92}$$

In the vertical plane including the line of maximum radiation, the wave from the system under discussion is horizontally polarized. At a point P at a great distance the field is the sum of the direct and reflected waves where proper account of the phase angle due to the greater distance of travel of the reflected wave is taken into account. From the geometry of Fig. 58 it is apparent that the reflected wave may

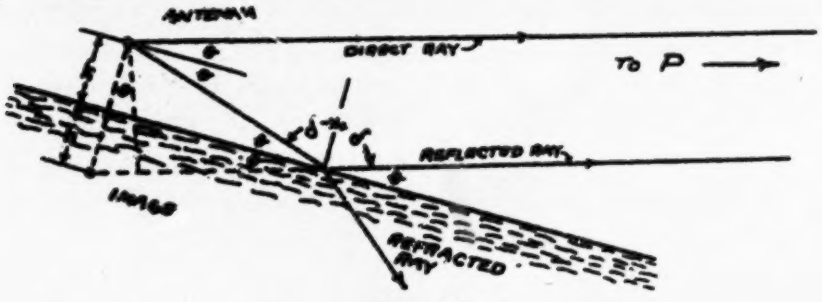


Fig. 58

be considered as originating at an image in which is flowing a current $K_1 I$ where I is the current in the antenna. The phase angle between the direct and reflected waves is then:

$$\psi = 4\pi \frac{h}{\lambda} \sin \theta. \tag{93}$$

Adding the two waves we obtain for the power P_g when reflection from ground is taken into consideration:

$$P_g = P_0 \left[1 + K_1^2 + 2K_1 \cos\left(4\pi \frac{h}{\lambda} \sin \theta \right) \right] \tag{94}$$

where P_0 is the power neglecting ground.

For the case of a perfect conducting ground the field at P is the sum of the fields due to the antenna and its negative image. The distributions of radiation in the vertical plane both for Rocky Point ground and a perfectly conducting ground have already been shown in Fig. 48. It is seen from this figure that, for this particular antenna system, the assumption of a perfect ground results in approximately the same distribution as that obtained for a dielectric. If the waves had been vertically polarized, the results would have been entirely different.

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605

In vertical planes other than that which we have termed *the* vertical plane, the waves from this antenna are elliptically polarized. The treatment of the reflected wave from dielectric ground in such a case is extremely laborious since the components parallel and normal to the plane of incidence must be considered separately. For this reason together with the fact that in this case there is no great error, the contour map in Fig. 49 was made assuming perfectly conducting ground. An exact mathematical treatment would probably be little nearer the truth since, under actual conditions, there are many factors which are not exactly known.

By placing two complete sections side by side along a line at right angles to the direction of the beam, the concentration of radiated power in the desired direction is approximately doubled. The distribution of power is obtained by adding together the fields due to each section while taking proper account of the phase angle. If X is the length of the line between the apexes of the two sections, the phase angle is $2\pi X/\lambda$ times the projection of this line upon the radius vector in the direction under consideration. In our system of spherical coördinates, the phase angle is:

$$\psi = 2\pi \frac{x}{\lambda} \sin\theta \cos\phi \tag{95}$$

and, from (85), we obtain for the power from the two-section system:

$$P_2 = 4P_1 \cos^2\left(\pi \frac{x}{\lambda} \sin\theta \cos\phi\right) \tag{96}$$

where P_1 is the power for one section alone.

To obtain the power for a four-section system we can combine two double-section systems. Then:

$$P_4 = 16P_1 \cos^2\left(\frac{\pi x}{\lambda} \sin\theta \cos\phi\right) \cos^2\left(2\pi \frac{x}{\lambda} \sin\theta \cos\phi\right). \tag{97}$$

For a three-section system the formula for power distribution is:

$$P_3 = P_1 \left[1 + 2\cos\left(2\pi \frac{x}{\lambda} \sin\theta \cos\phi\right)\right]^2. \tag{98}$$

Contour maps showing the distribution of power for one-, two-, and three-section systems at a mean height of one wavelength above perfect conducting ground has been shown in Figs. 49, 50, and 51.

Figs. 59 and 60 show the power distribution in a plane inclined at 10.5 degrees to the horizontal, the vertical angle of maximum radiation.

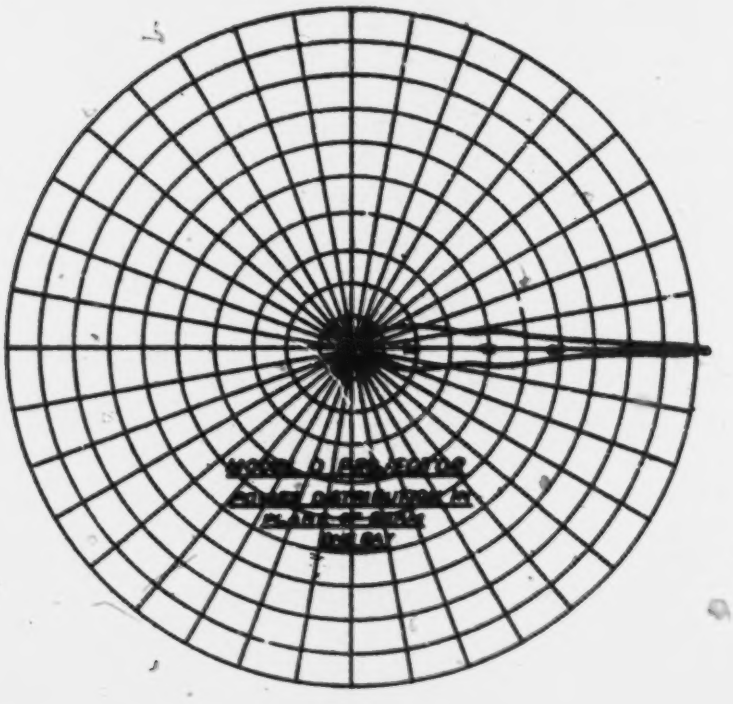


Fig. 59

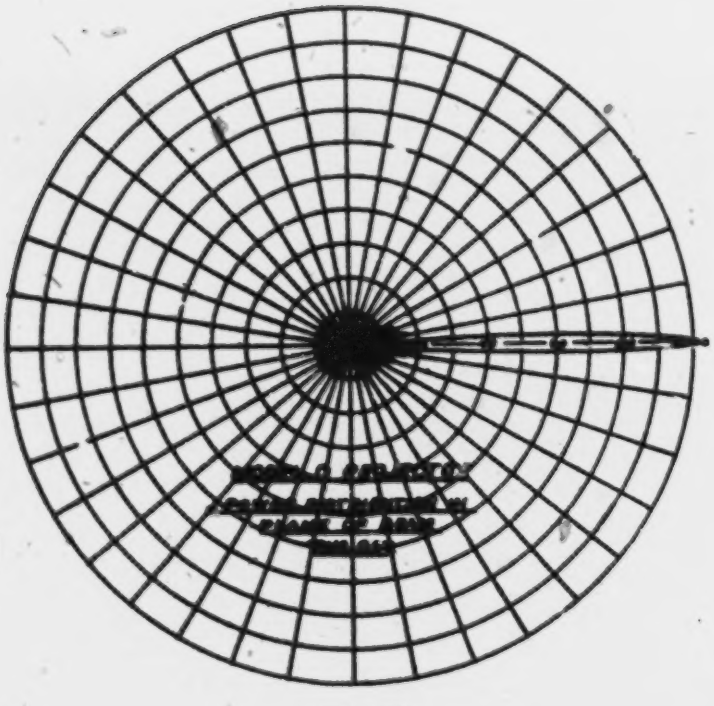


Fig. 60

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794

The directivity is, according to the definition given:

$$D = \frac{\bar{P}_{max}}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} \bar{P} \sin\theta d\theta d\phi} \tag{99}$$

The expression for $\bar{P}$ is so extremely complex that the evaluation of the surface integral by other than graphical or mechanical processes would no doubt be impractical. The computations necessary to determine the curves for evaluating by means of a planimeter involve a large amount of labor even when carried out with slide-rule accuracy. The following table gives the directivity, and power ratio to a half-wave dipole as arrived at by such calculations:

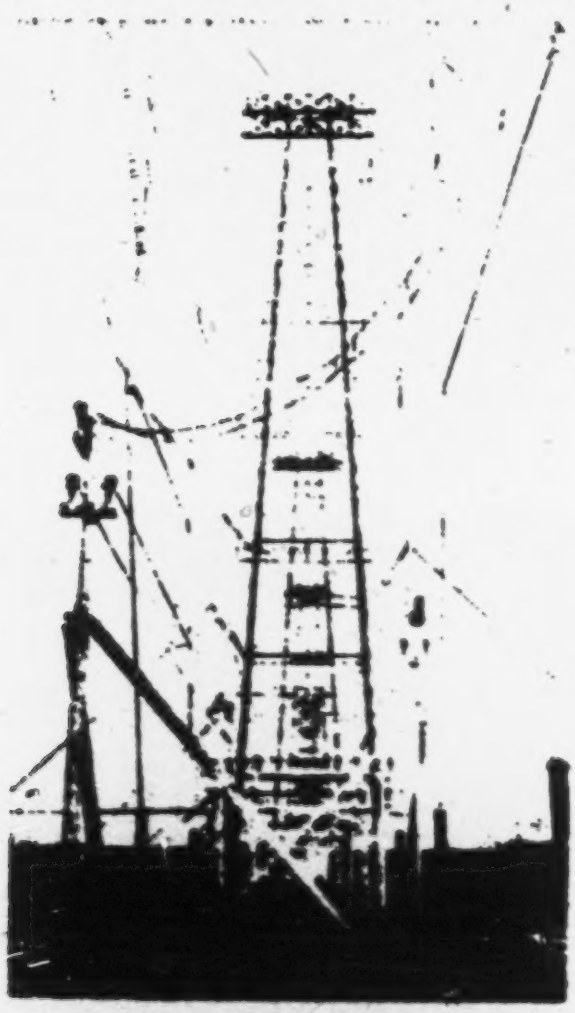
Number of Sections	*Directivity*	*Power Ratio to Dipole*	*Decibels Gain Over Dipole*
One	64	39	15.9
Two	128	78	18.9
Three	192	117	20.7
Four	256	156	21.9

Such theoretical calculations cannot completely determine the effectiveness of antenna systems because they do not take into account the phenomena of propagation between transmitter and receiver. It has been found by experiment that the actual results obtained are as would be expected from the calculations.



PLAINTIFF'S EXHIBIT No. 22

SHORT-WAVE TRANSATLANTIC RADIO-TELEPHONY



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A general view of the transmitting station at Lawrenceville, New Jersey

Fairchild Aerial Surveys, Inc.

The American Radio Stations

By W. WILSON
Assistant Director of Research

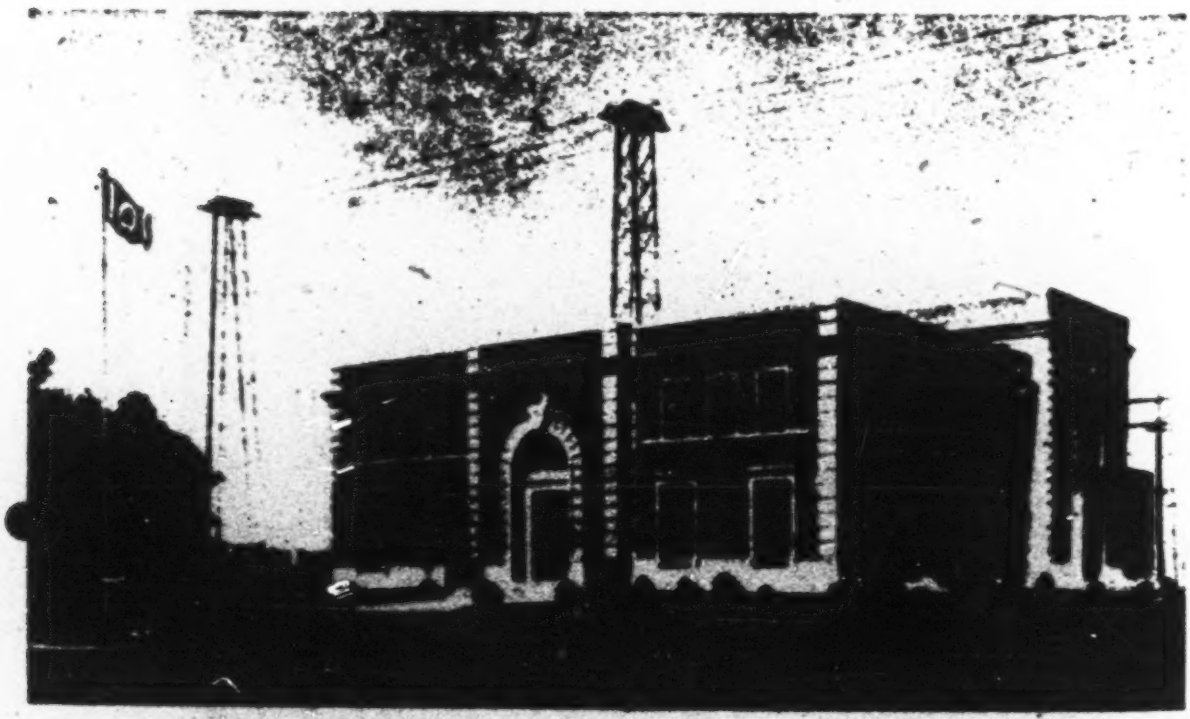
NEW short-wave stations for transoceanic communication have been opened at Lawrenceville, New Jersey, for transmitting and at Netcong, New Jersey, for receiving.

Four channels will be put into operation. One of these will replace the present experimental channel, through which messages have been transmitted from our Deal Beach station and received at Netcong for the last two years.

Two of the others will be added to the European service during the coming months, and the fourth will establish telephone communication with South America.

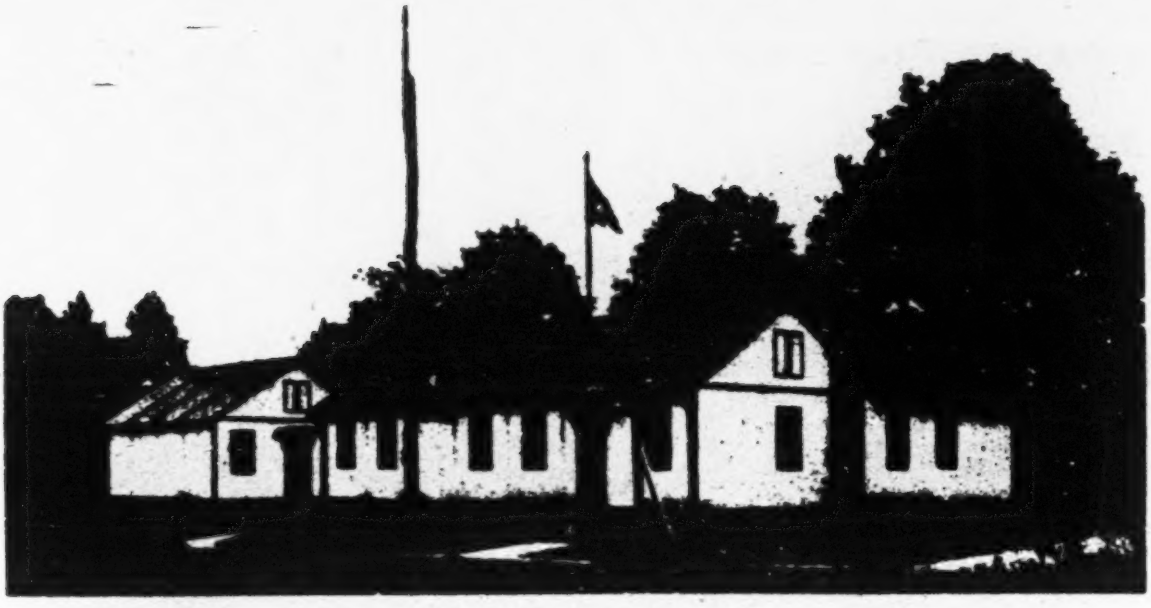
The Lawrenceville property is approximately 800 acres in extent and has two buildings The main building houses the general offices and line terminal equipment in addition to two of the radio transmitters. The second building is similar to the first except that provision is merely made for the radio equipment.

Each transmitter is designed for operation on those frequencies in the short-wave range which are found to be necessary for communication during the hours of operation. These frequencies are approximately 19,000, 14,000, and 9,000 kilocycles, corresponding to 16, 22, and 33 meters wavelength.



Antenna towers and main building at Lawrenceville

799



Buildings at Netcong

Carrier power at these frequencies is obtained by amplification of the suitable harmonics from crystal oscillators with fundamental frequencies in the neighborhood of 3,000 kilocycles. Considerable care is taken with regard to constancy of temperature and other operating conditions to ensure the stability of these oscillators.

By the usual method of plate modulation, the voice signals are applied to the carrier, and the modulated power is in turn amplified by two stages employing water-cooled tubes. The output from the sets is fed by transmission lines to appropriate antennas, located in some cases several hundred feet away.

Power for the transmitter is purchased from central-station lines. After transformation to appropriate voltages, that required for plate circuits is rectified and filtered. For the two final stages power is delivered at 10,000 volts from a rectifier employing six water-cooled tubes. Elaborate precautions are taken to insure safety in operation by an interlocking system which prevents the opening of any enclosure before the power has been shut off. In addition the doors of the apparatus are equipped with safety switches which throw the main circuit breaker when the doors are opened if there should be any failure of the interlocking system.

One of the advantages of a short-wave system is its adaptability to the use of antennas which concentrate the transmitted energy into a beam in the direction required. This greatly enhances the signal at the receiver.

In general, directive antennas are suitable for only one wavelength. Since each transmitter must be able to work on any of three wavelengths, nine antennas are required. These consist of curtains of vertical and horizontal wires strung between towers 180 feet high and 250 feet apart. Each antenna is 500 feet wide and the nine antennas are lined up end to end giving a total length of 4500 feet. The gain to be expected from the use of these antennas over a single vertical wire is from fifteen to twenty decibels.

The Netcong receiving station com-

22/4



Engineers in charge of the development of the short-wave radio transmitters and receivers. Left to right: A. A. Oswald, M. J. Kelly, W. Wilson, R. A. Heising, J. C. Schelleng, H. T. Friis

prises about 400 acres. As in the case of the transmitting station three wavelengths are needed for each of four receiving sets, necessitating the use of 12 antennas. Each receiving set is housed in a separate building and the general offices and power plant are in still another building.

The receiving sets have two stages of radio-frequency amplification, six stages of intermediate amplification and one stage of audio amplification. An automatic volume control minimizes fading effects. Actual volume at which the energy is put on the telephone line is adjusted by means of repeaters in the line terminal equipment.

The antennas used at the receiving end are also directive. Their directivity not only makes them more efficient from the standpoint of picking up signals from a preferred direction but it also by its discrimination against signals coming from other directions materially reduces interference both from static and from other stations. The antennas are six wavelengths long and are connected to their respective sets by transmission lines.

In selecting a site for the receiving station great care was taken to avoid the proximity of well-travelled automobile and airplane routes, because of the interference with signals created by unshielded ignition systems. With the adoption of radio communication for airplanes their ignition systems must perforce be shielded but no relief can be expected from interference from the present type of automobile engine. Limits have been prescribed beyond which automobiles are not permitted unless their ignition systems are adequately shielded. Horses are used for much of the transportation immediately around the station.

Transmitting Antennas

By E. J. STERBA
Radio Research

THE antenna system is the first object to attract the attention of a visitor to the plant at Lawrenceville, N. J., for the tower line west of Princeton is visible several miles from the station. Upon arriving at the station grounds, the antenna system appears to be a complicated network of wires on rugged towers extending more than a thousand feet past the observer. Appreciating that this extended construction is associated with directive transmission, he may feel that the structure is far too complicated for ready explanation. Yet the fundamentals of directive transmission and thus of the antenna are quite simple.

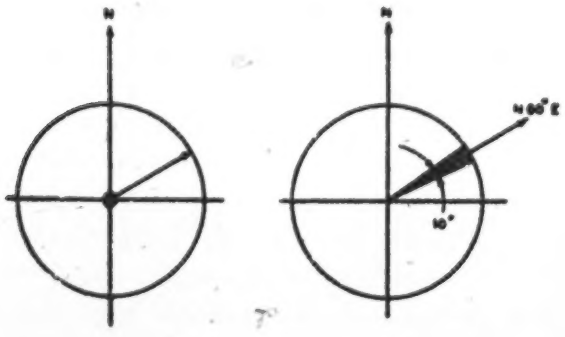


Fig. 1-A (left)—Electric intensity about a broadcast transmitter. The area of the circle is proportional to the power radiated; Fig. 1-B (right)—Shaded area represents energy radiated if transmission is confined to a ten-degree sector

A background of broadcast experience has familiarized nearly everyone with a transmitting antenna. The broadcast antenna is constructed so as to radiate in all directions with equal intensity, because broadcast reception is generally desired in all directions about the station. For this purpose a single vertical wire or several closely spaced vertical wires may be employed. If a vertical-wire antenna is erected upon an ideal transmitting site, the electric intensity in any direction about the antenna and for a constant distance from the antenna may be represented by the radii of a circle (Figure 1-A), signifying equally good reception in all directions about the antenna. The area of the circle is approximately proportional to the power radiated.

If, however, radio transmission is required only between two points, the radiation of energy in all directions other than that in which the receiving station lies is wasted effort. Suppose, for example, that the receiving station is located at N60°E with respect to the transmitter. If some modification is made in the antenna so that radiation occurs only between the radii five degrees to either side of the direction to the receiving station, and if the power of the radio transmitter is readjusted so that the signal-strength from the simple antenna and from the modified antenna are equal at the receiving station, the area of the shaded ten-degree sector in Figure 1-B is proportional to the power radiated—10/360 of that required

for the simple antenna. If this ideal case could be set up, the radio transmitter connected to the modified antenna would consume one thirty-sixth of the power formerly consumed. In telephone nomenclature, an equivalent signal strength would be secured from a source 15.6 decibels lower in power level. It is thus of some economic importance to determine how an antenna may best be modified so that radiation is confined to a narrow sector within which lies the chosen direction.

Heinrich Hertz, who in 1887 and 1888 discovered means for producing and detecting radio waves, constructed the first directive antenna. Employing wavelengths of less than one meter, Hertz experimentally concentrated radio waves in a chosen direction by means of a short antenna lying in the focus of a metallic parabolic surface (Figure 2). In principle the scheme was very much like that of an automobile headlight. Hertz also observed that radio waves of the same length from different sources produced interference patterns—recurring positions of intense and feeble signal-strength—near the sources.

Parabolic reflectors similar to Hertz's experimental antenna have been employed for a number of years in short-wave radio transmission. It is essential that the dimensions of the parabolic reflecting surface be several wavelengths, and hence it is impracticable that the surface be a conducting sheet except for use at very short wavelengths. This difficulty was overcome by using a number of wires, spaced so as to outline the surface, and set at critical lengths so as to be resonant at the operating wavelengths.

Interference, well known with light waves and observed by Hertz with radio waves, is an alternative method for producing directive transmission.* If two or more narrow parallel slit-sources of monochromatic light are directed upon the same surface an interference pattern is produced, visible as a family of light and dark strips. It is brought about by the difference in phase of the radiation from the two

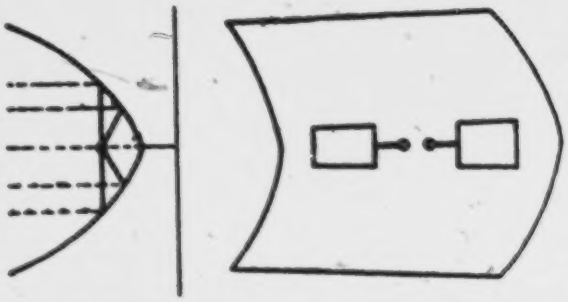


Fig. 2—Parabolic reflector employed by Hertz. The antenna is at the focus of the metallic parabolic surface

sources due to the difference in length of path between the two sources and the screen.

Directive radio transmission by means of wave interference may readily be obtained by transmitting simultaneously from the same transmitter with two or more suitably spaced antennas. If two antennas, one wavelength apart and each carrying unit current, are driven in phase, the electric intensities from both antennas, several wavelengths away in the direction normal to the two, are in phase because the paths from the antennas to the receiving point are equal. The field in this direction is the sum of the fields from the individual antennas. If, however, a direction thirty degrees from the normal is considered, the path from one antenna is one-half wavelength longer than from the other, and the time it consumes

* *The "reflectors" discussed in the preceding paragraph depend ultimately, of course, on interference also.*

in traveling this additional distance puts the radiation from one antenna one-half period behind the other. The intensities in this direction are exactly out of phase and thus the net intensity is zero. By simple trigonometry



Fig. 3—Directive intensity characteristics for: (A) two antennas spaced one wavelength apart and driven in phase; (B) two antennas spaced one-quarter wavelength apart and driven ninety degrees out of phase (B leads B')

the polar diagram of Figure 3-A may be obtained, representing the intensity in all horizontal directions about the antenna. The radii of the circle enclosing the four-leaf figure represents the intensities which would be realized if the two antennas were very close together.

Forming an example of another simple directive system are two antennas spaced one-quarter wavelength apart and driven ninety degrees out of phase with each other. Since a quarter period is consumed in traveling the distance between antennas, the radiations from the antenna which bears the current lagging ninety degrees will lag an additional ninety degrees upon arriving at the adjacent antenna, and the fields from the two antennas will cancel in this direction. In the opposite direction the fields both lag the same amount and are additive. The polar diagram for this case is given in Figure 3-B, in which again the circle enclosing the figure represents the radiations which would proceed from the two antennas if these were coincident and in phase. It has been found by experiment that two antennas will form this second system if one is driven by the transmitters and the other is parasitically excited. The parasitic antenna is usually called the "reflector antenna."

The above two schemes may be combined in several possible ways to give unidirectional systems. In general the polar diagram of the combined system may be obtained by superimposing the two diagrams and multiplying by each other the lengths of the coincident radii to obtain the lengths of the new radii.

Simple directive systems, such as

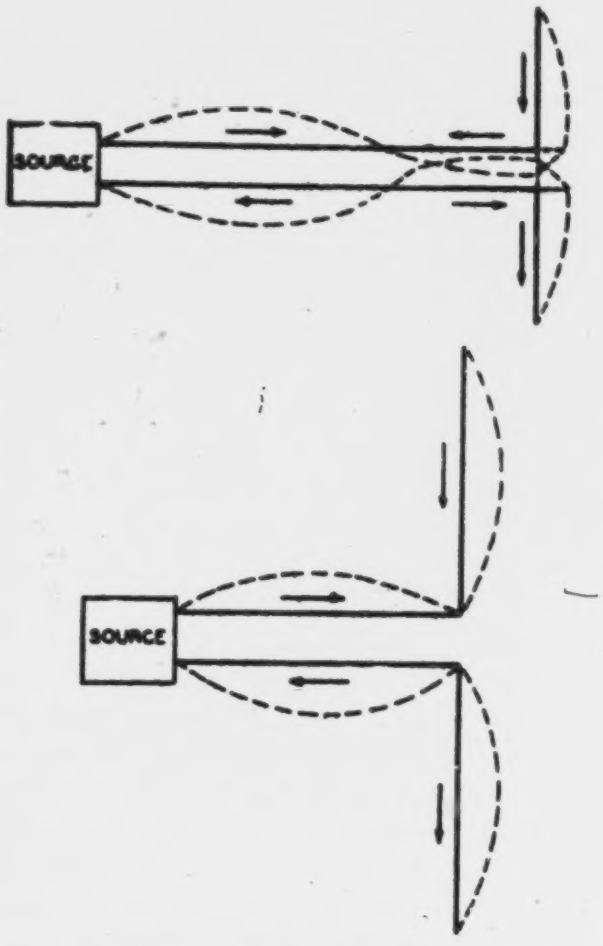


Fig. 4-A (above)—Line bent into a Hertz antenna; Fig. 4-B (below)—Line bent into two Hertz antennas

those described, were proposed by S. G. Brown in 1899 and J. S. Stone in 1901, and many others have since devised increasingly complex and more efficient schemes. Later G. A. Campbell, of the American Telephone and Telegraph Company, proposed a directive scheme comprising several rows, each bearing several antennas in suitable phase relations. He established in a general manner the relations between the spacings and phasings and devised methods whereby the performance of the system, however complex, could be predicted.

In the polar diagrams, the area of the figure, as compared to the area of the enclosing circle, is approximately proportional to the relative power consumption of the directive and the non-directive systems and thus an approximation of the gain of the directive system may be obtained by expressing the ratio of the areas in transmission units. The reason for this gain may be suggested by another simple example. If two antennas, several wavelengths apart, each have a resistance R and carry a current I, the total power consumed is $R I^2 + R I^2 = 2 R I^2$. The intensity at a point where the radiations are in phase is proportional to 2 I. This same intensity could be obtained by exciting one antenna alone with 2 I units of current but the power consumption would then be $4 R I^2$, or twice as much as before. In general the improvement factor of a directive antenna is nearly proportional to the number of antennas, when they are separated by more than about one-half wavelength. This is only approximately true because two antennas, when close together, react upon each other.

There are many methods for the mechanical construction of directive antennas; that now being employed at Lawrenceville depends upon the manner in which waves stand upon transmission lines. It is generally known that the current in an open-circuited line recurs along it in standing maxima

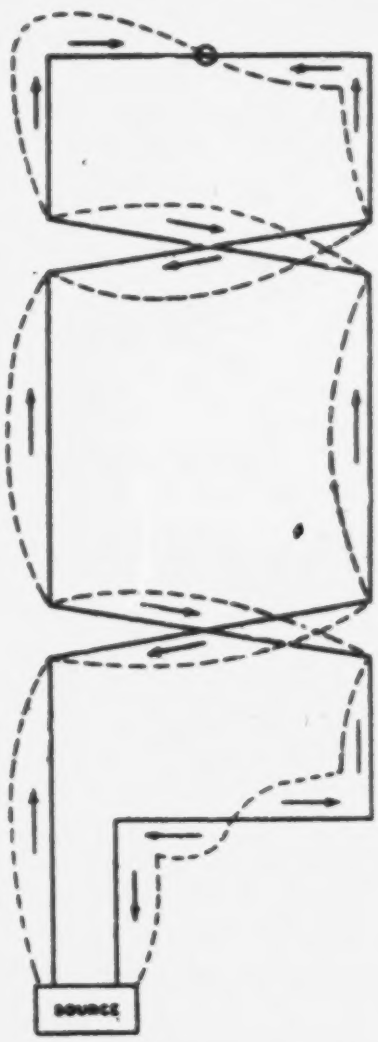
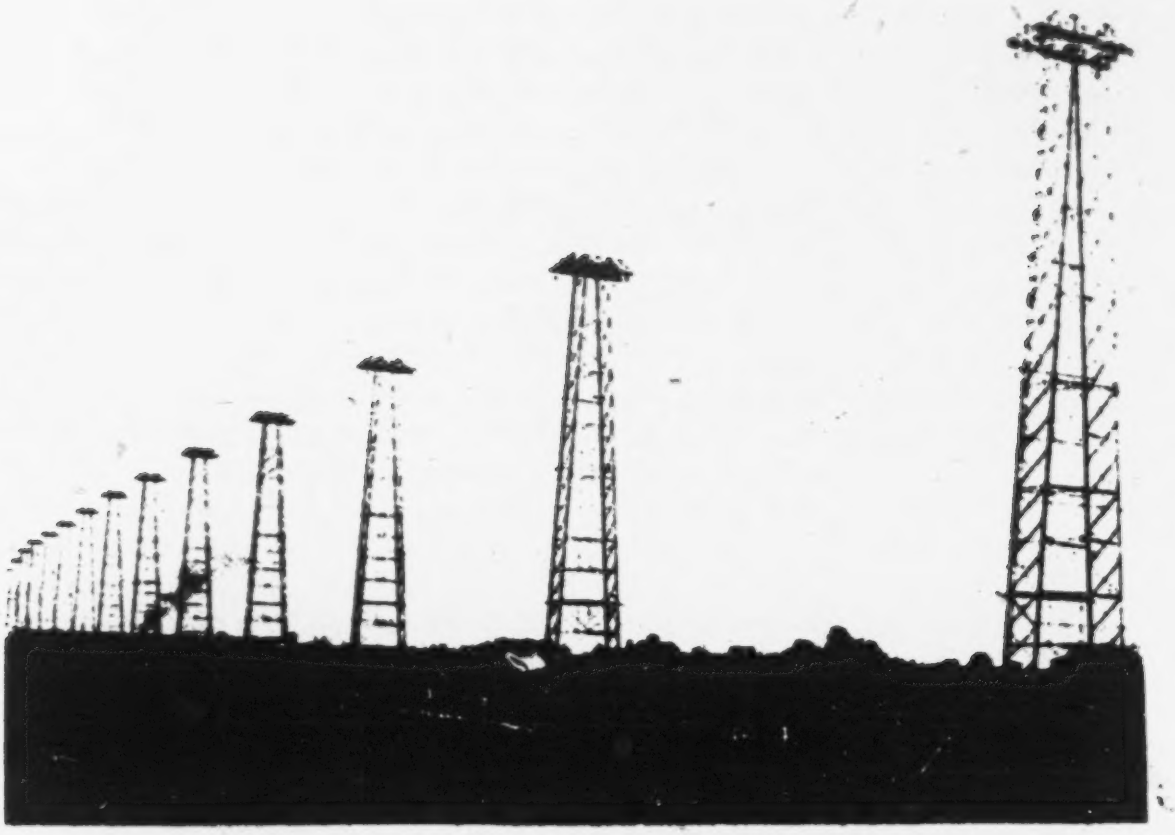


Fig. 5—A panel for the Lawrenceville antenna system. The vertical members are radiators; the crossed members are transmission-line phase shifters. The line may be open or closed at the center of the top cross-piece, since there is a standing-wave node, and thus no current flow, at that point

and minima, that the phase difference between successive current maxima is 180 degrees and that the phase difference between corresponding points



A part of the line of towers supporting the antennas

on the two wires is 180 degrees. The radiation from an open-circuited line is small, but if the ends of the line are bent outward, the radiation from these ends will be greatly augmented and the balance of the line will act largely as a means for transmitting power to the radiating end. If the bent portions are each one-quarter wavelength long, a one-half wave Hertz antenna is formed (Figure 4-A). An even more efficient antenna may be formed by bending over a one-half-wave portion of the line; in this case the bent-over portion is equivalent to two Hertz antennas driven in phase (Figure 4-B).

Thence it is only a small step to the panel arrangement of the Lawrenceville antenna system (Figure 5). Here the vertical wires are the radiating members, all excited in phase, and the horizontal pairs are transmission lines for distributing the current to the radiating elements in the desired phase-relations. The panel is equivalent to four Hertz antennas, two of which are stacked one above the other and of which the two groups thus formed are spaced one-half wavelength apart. Complete reinforcement of signal intensities takes place only in the horizontal direction normal to the panel. In all other directions destructive interference occurs; complete cancellation occurs in the plane of the panel.

By computation and by experiment it has been shown that a power improvement of four decibels is acquired from the horizontal spacing of one-half wavelength, and of two decibels from the vertical stack of two. The net power saving is approximately six decibels: the panel consumes but one-fourth the power which would be re-

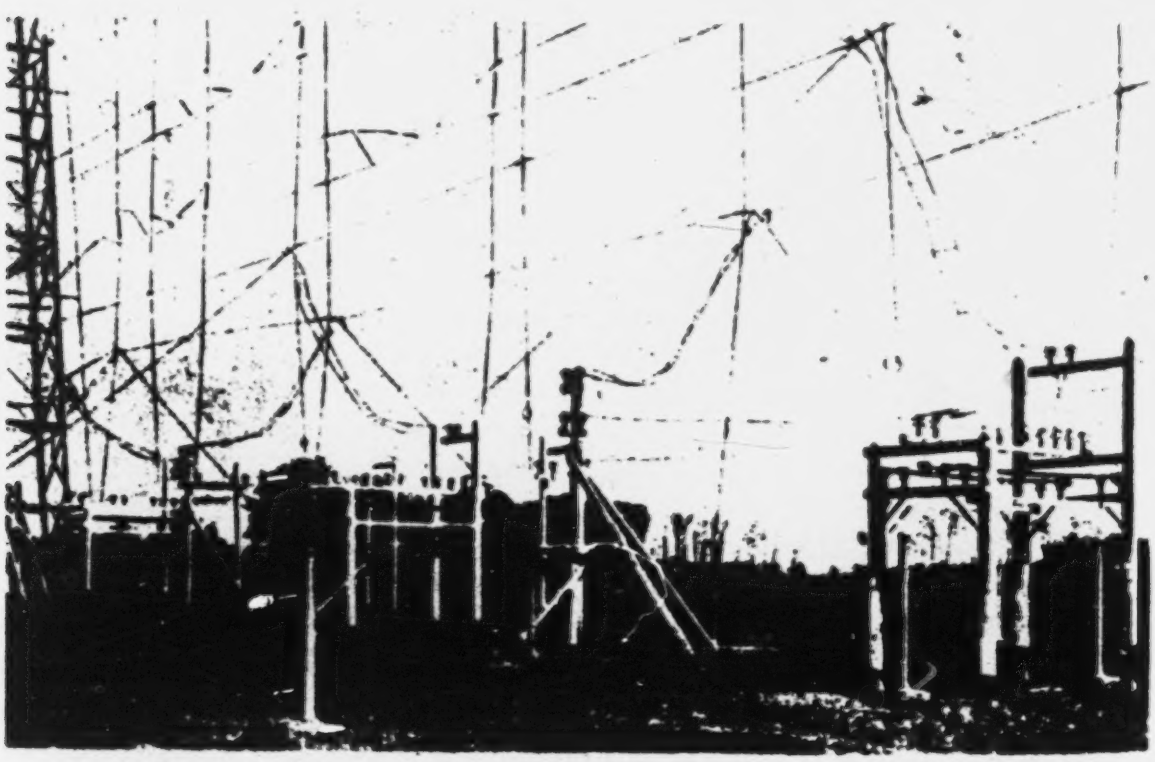
quired by one element to produce the same intensity in the chosen direction.

A second similar panel, excited parasitically, is placed one-quarter wavelength behind the first to act as a reflector and thereby create an unidirectional system. It has been found that the reflector reduces the power required to maintain a given intensity in the desired direction by approximately three decibels, and thus brings the gain of the two-panel system up to nine decibels. The two-panel system, therefore, requires but one-eighth the power which would be necessary in a simple antenna producing the same intensity in the desired direction.

Larger power savings may be effected by employing many antennas properly connected together. Practically, however, considerations of mechanical construction, investment and maintenance limit the size of the system. The complex nature of short-wave transmission also leads to a lowering of the optimum size of the antenna. For wavelengths of the order of sixteen meters, improvements of twenty decibels (a power ratio of one hundred) are practicable.

The connection of a number of antenna panels to a common feeder line must accomplish proper phase and impedance relationships. The former may readily be obtained through adjusting the lengths of interpanel lines, by tape-line measurements. The conventional methods for building up the load impedance to the surge impedance of the feeder line, however, are far from satisfactory for high-power work at short wavelengths. In this case one of the less familiar properties of a transmission line is used for transforming impedances.

If a line of surge impedance Z_o, exactly one-quarter wavelength long, is terminated with a load Z_r, the



Lower edge of antenna curtain, and frames supporting the quarter-wave lines for effecting sleet-melting connections and proper terminating impedances

sending-end impedance of the line is Z_0^2/Z_r and, if Z_r is a pure resistance, the sending-end impedance is a pure resistance. Such a quarter-wave line is employed in the Lawrenceville antenna system. Since a line bearing standing waves is being terminated at one upon which standing waves are not desired the receiving-end of the quarter-wave line is connected at either a current maximum or minimum, to ensure a resistance load.

A transmitting antenna is adversely affected both mechanically and electrically by sleet. The sleet load may strain the system to the breaking point and thus put the antenna out of service for a long period, and the mass of ice, having a dielectric constant of eighty, may detune the antenna and destroy the effectiveness of the system. Sleet is, therefore, removed in the Lawrenceville system, by heating

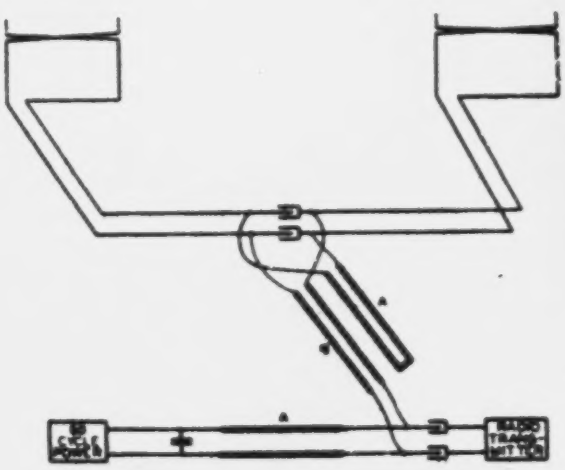
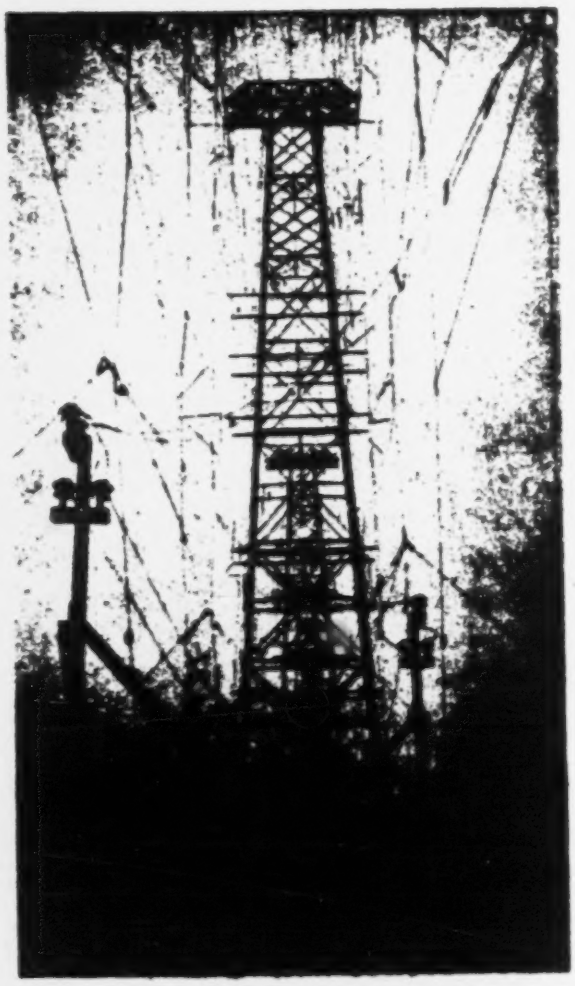


Fig. 6—Antenna connections for melting sleet from the Lawrenceville antenna

the wires with low-frequency currents of about 150 amperes at a potential of nearly a thousand volts in each antenna. All elements in the antenna are arranged to be in series for the low-frequency currents and the vertical elements in phase for the radio-frequency currents (Figure 6).

Another relatively unfamiliar property of transmission lines is utilized to effect this arrangement. If a line one-quarter wavelength long is short-circuited at the receiving end, the sending-end impedance is very large. Such a line may be connected across a circuit of relative low impedance without disturbing its radio-frequency functions. From Figure 6 it may be seen that the anti-resonant circuit of quarter-wavelength bars, in combination with several condensers which readily pass radio frequencies but which block low frequencies, and in combination with two antenna panels, forms a series



Looking down a tower line at Lawrenceville. Photo by G. M. Eberhardt of the Research Department

circuit for the low-frequency currents and the power source. The two panels, however, are in parallel with each other and with the feeder line at radio frequencies. Both the low and the high-frequency powers may be applied simultaneously to the antenna.

For three of the four communication channels at the Lawrenceville radio plant, the antenna system is supported by a row of nineteen towers at right angles to the direction of England; for the fourth, a row of seven towers is placed at right angles to the direction of Buenos Aires. Guys run along the top of these towers to anchors on the ground at the ends of the rows. The towers, 250 feet apart and 180 feet high, are designed to withstand the load of the largest antenna that can be supported in a bay, when covered with a coating of ice one-half inch in radius and subjected to a gale of ninety miles per hour. Each antenna occupies two tower-bays. The antenna-curtains themselves are supported by messenger cables and may be lowered or hoisted by individual winches; the curtains are constructed from No. 6 B&S wire and are held in position by insulated sections of steel harness. The several panels in each curtain are interconnected by transmission lines which lead to frames where proper connections are made and impedances built up to terminate the power leads from the radio transmitters.

The practicability of directive systems is dependent upon the shortness of the transmitted wavelengths. A twenty decibel antenna, operating on five hundred meters, would be approximately ten wavelengths or fifteen thousand feet long and two wavelengths or three thousand feet high. The investment in such a plant would probably never return dividends. Fortunately the wavelengths used in the transoceanic short-wave system are such that directive effects can economically be obtained.



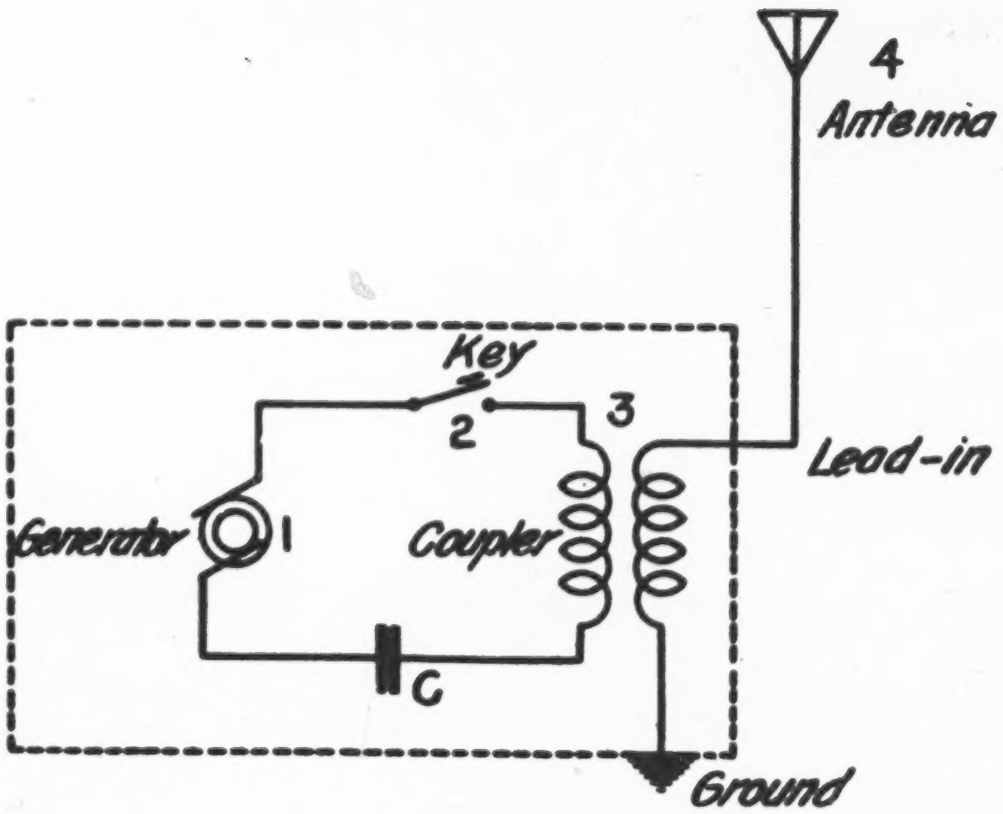
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PLAINTIFF'S EXHIBIT No. 27



ELEMENTARY DIAGRAM OF RADIO TRANSMITTER

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CHART OF WAVELENGTHS AND CORRESPONDING

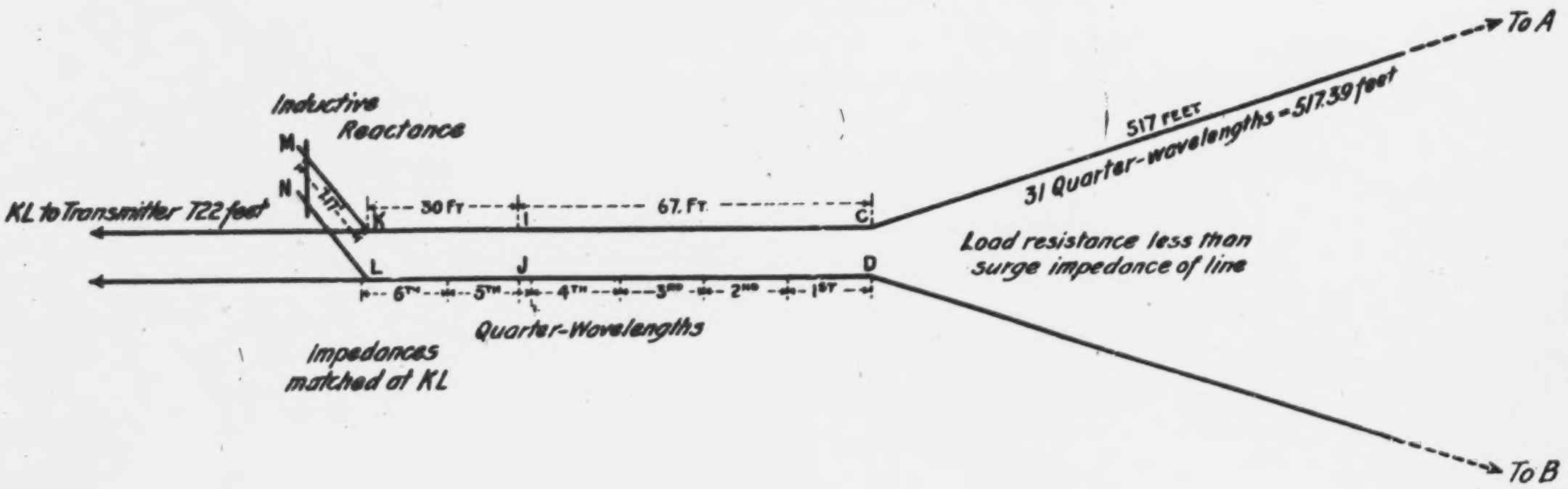
RADIO FREQUENCIES

Wavelength	Frequency	
20,000 meters	15,000 cycles	or 15 kilocycles
15,000	20,000	20
10,000	30,000	30
5,000	60,000	60
3,000	100,000	100
1,500	200,000	200
1,000	300,000	300
600	500,000	500
300	1,000,000	1,000
200	1,500,000	1,500
150	2,000,000	2,000
100	3,000,000	3,000
50.08	5,990,000	5,990
29.5	10,170,000	10,170
20.35	14,740,000	14,740
14.3	20,980,000	20,980
10.	30,000,000	30,000

IMPEDANCE MATCHING OF ANTENNA SYSTEM No. 2 (ORIGINAL) - WML

Wavelength 20.35 Meters - 66.77 Feet

Quarter-Wavelength - 5.09 Meters - 16.69 Feet



Not drawn to scale

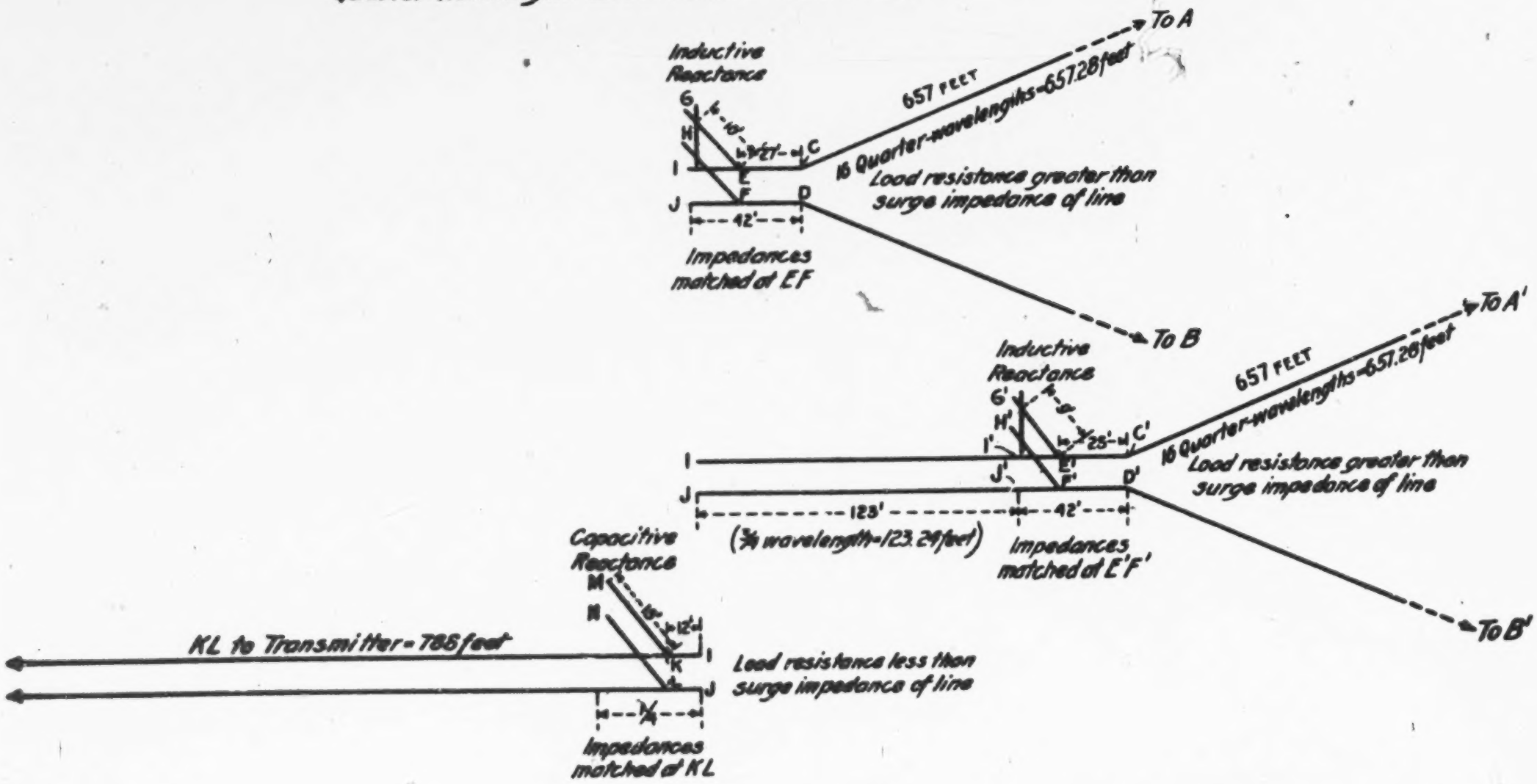
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626 815

IMPEDANCE MATCHING OF ANTENNA SYSTEM No. 8 - WMZ

Wavelength 50.08 Meters = 164.3 Feet

Quarter-Wavelength = 12.52 Meters = 41.08 Feet



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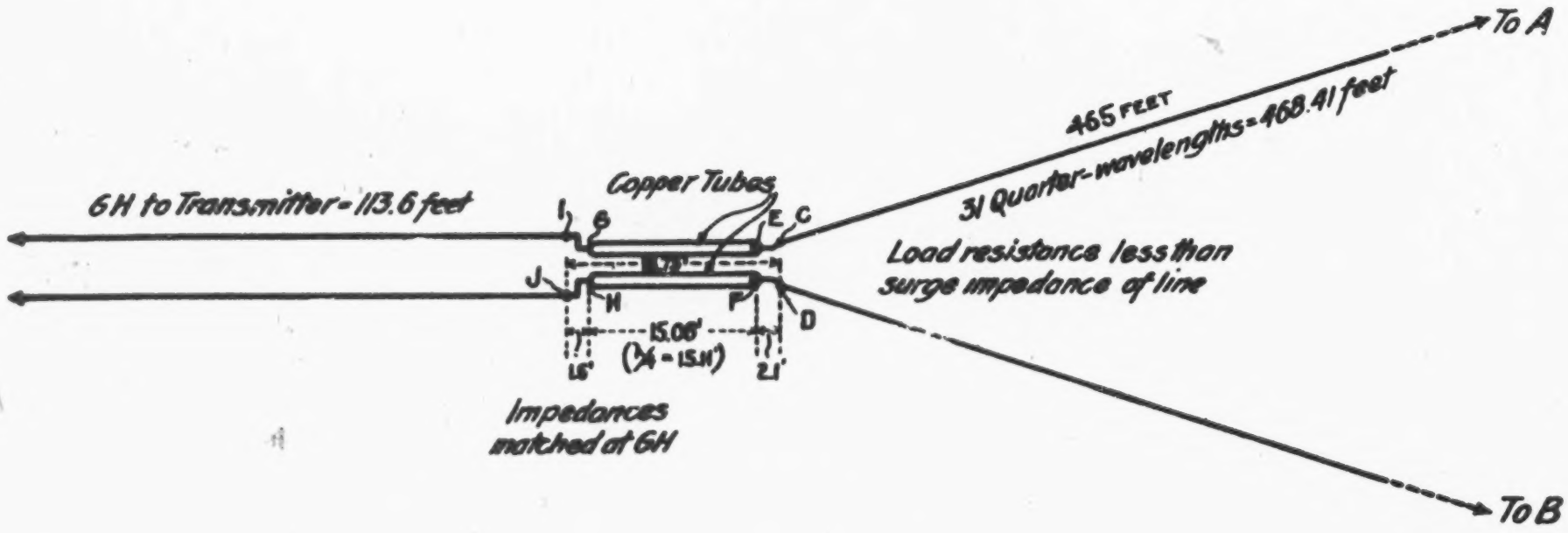
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IMPEDANCE MATCHING OF ANTENNA SYSTEM No. 11 - WKS

Wave length 18.42 Meters - 60.44 feet.

Quarter-wave length = 4.605 Meters = 15.11 Feet



Not drawn to scale

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Free Space
4 λ wire



Fig. 1

Perfect Ground

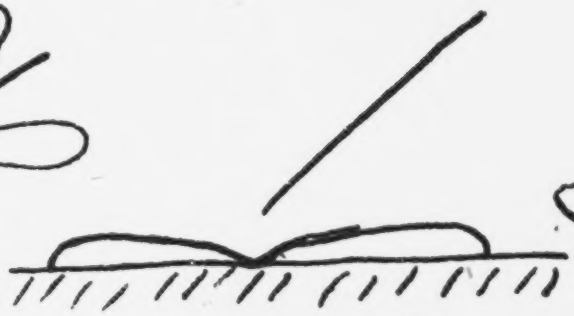


Fig. 4

Practical Ground



Fig. 5

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United States District Court
Eastern District of New York
Exhibit 36
Date Jan-15/36 in Evidence Jan 20/36
Clerk
Deputy Clerk

"V" with 4 λ wires
(correct angle)

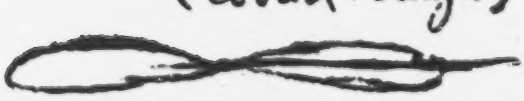


Fig. 2



Fig. 3

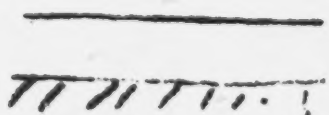
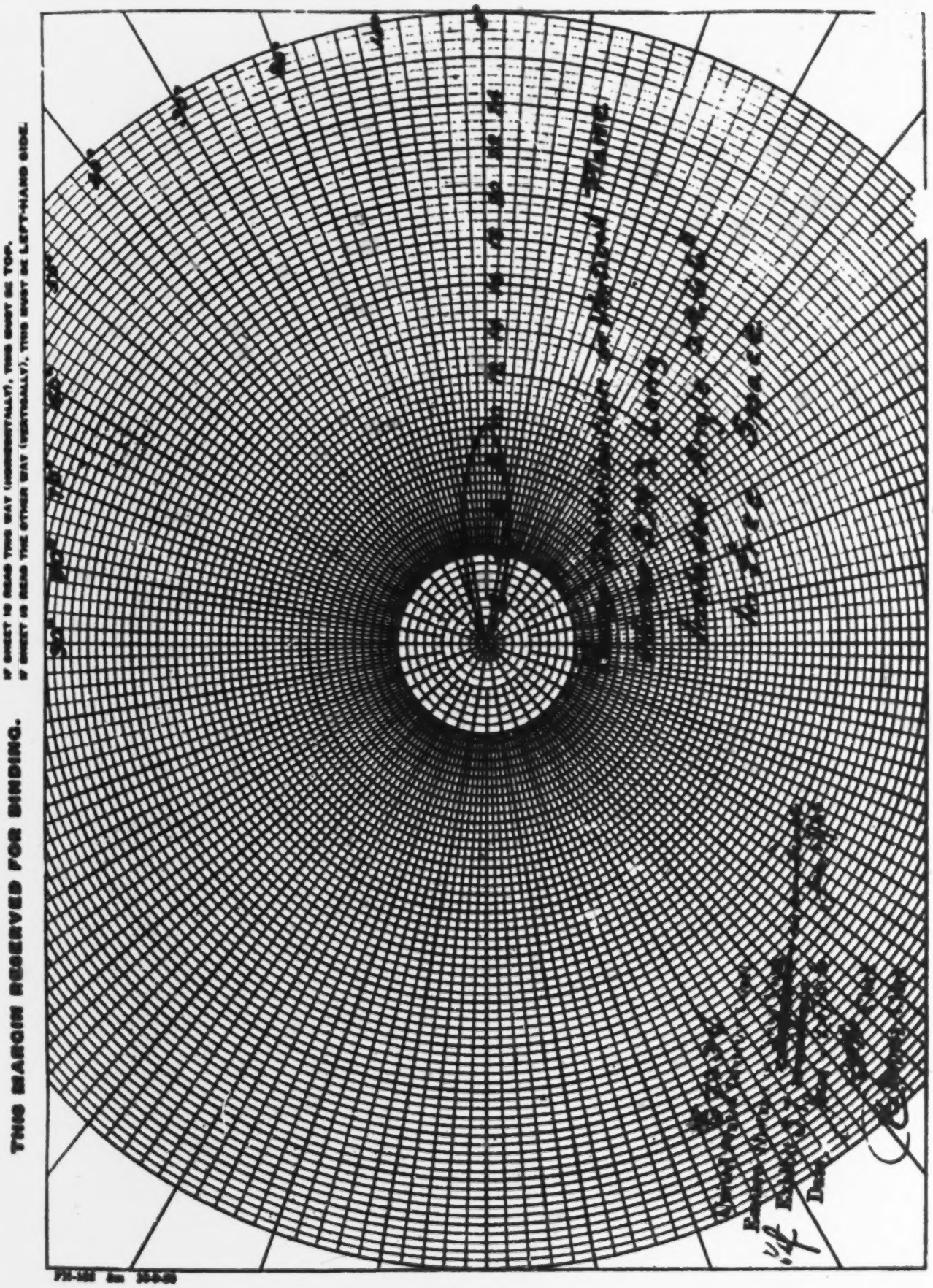


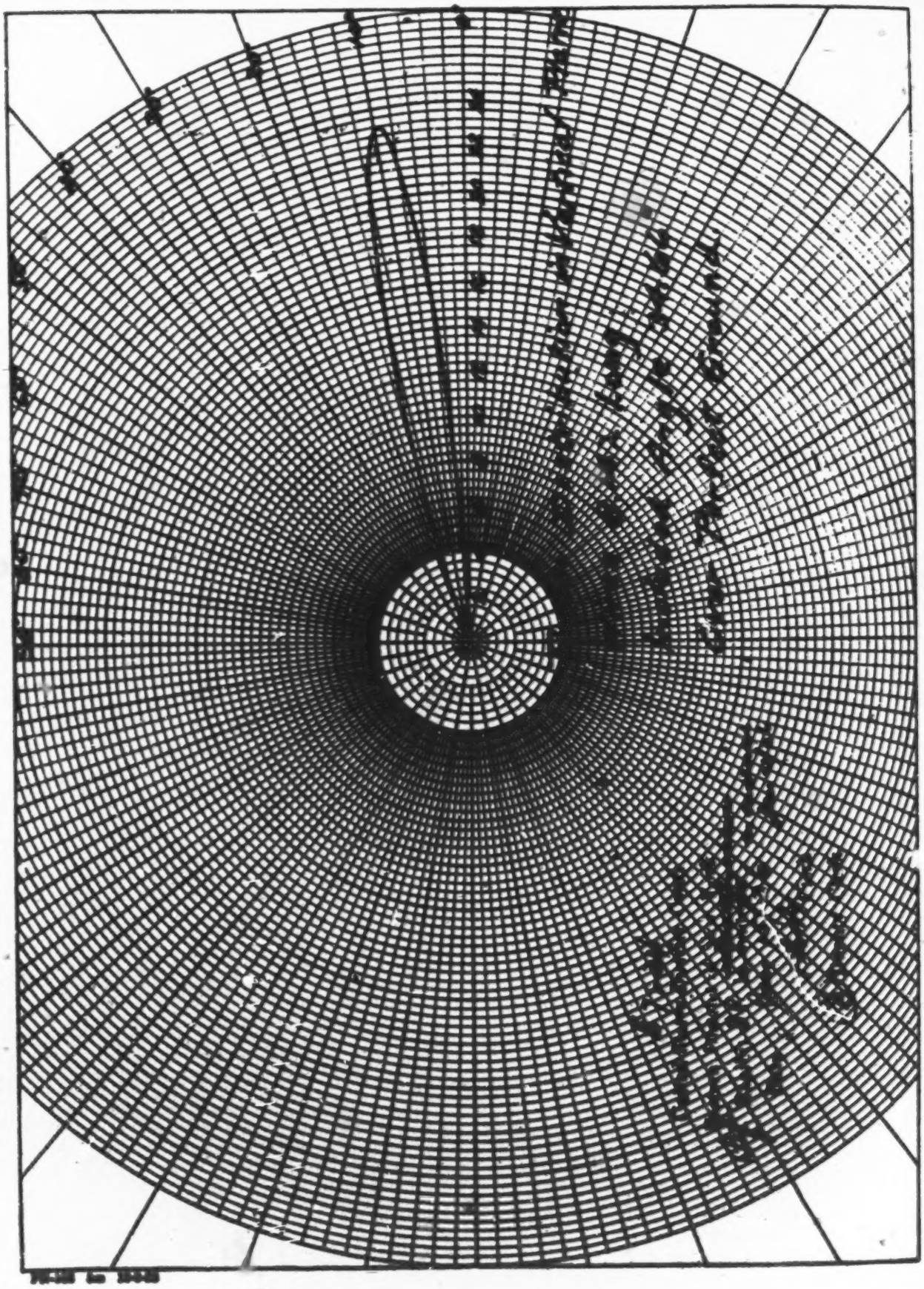
Fig 4

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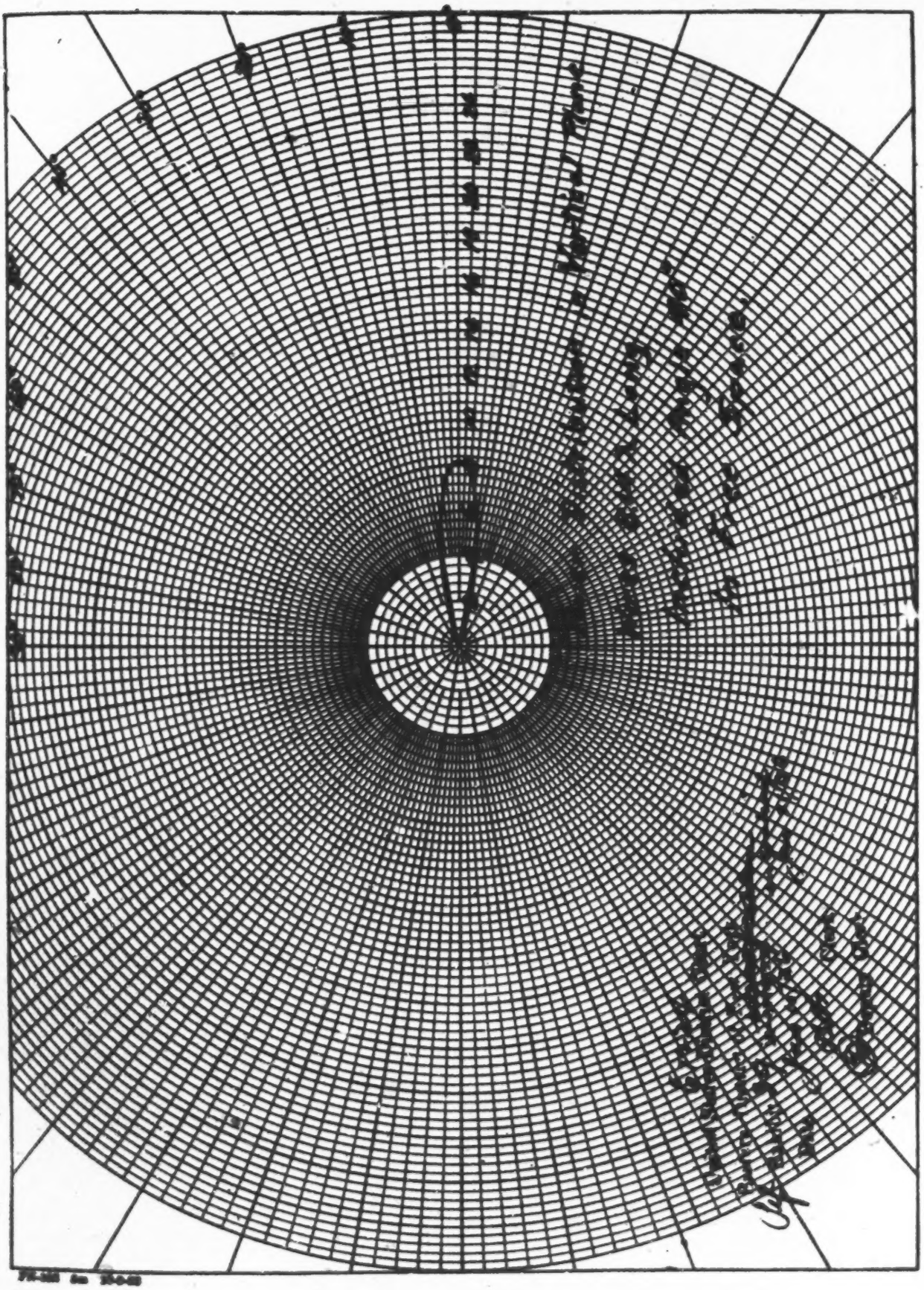


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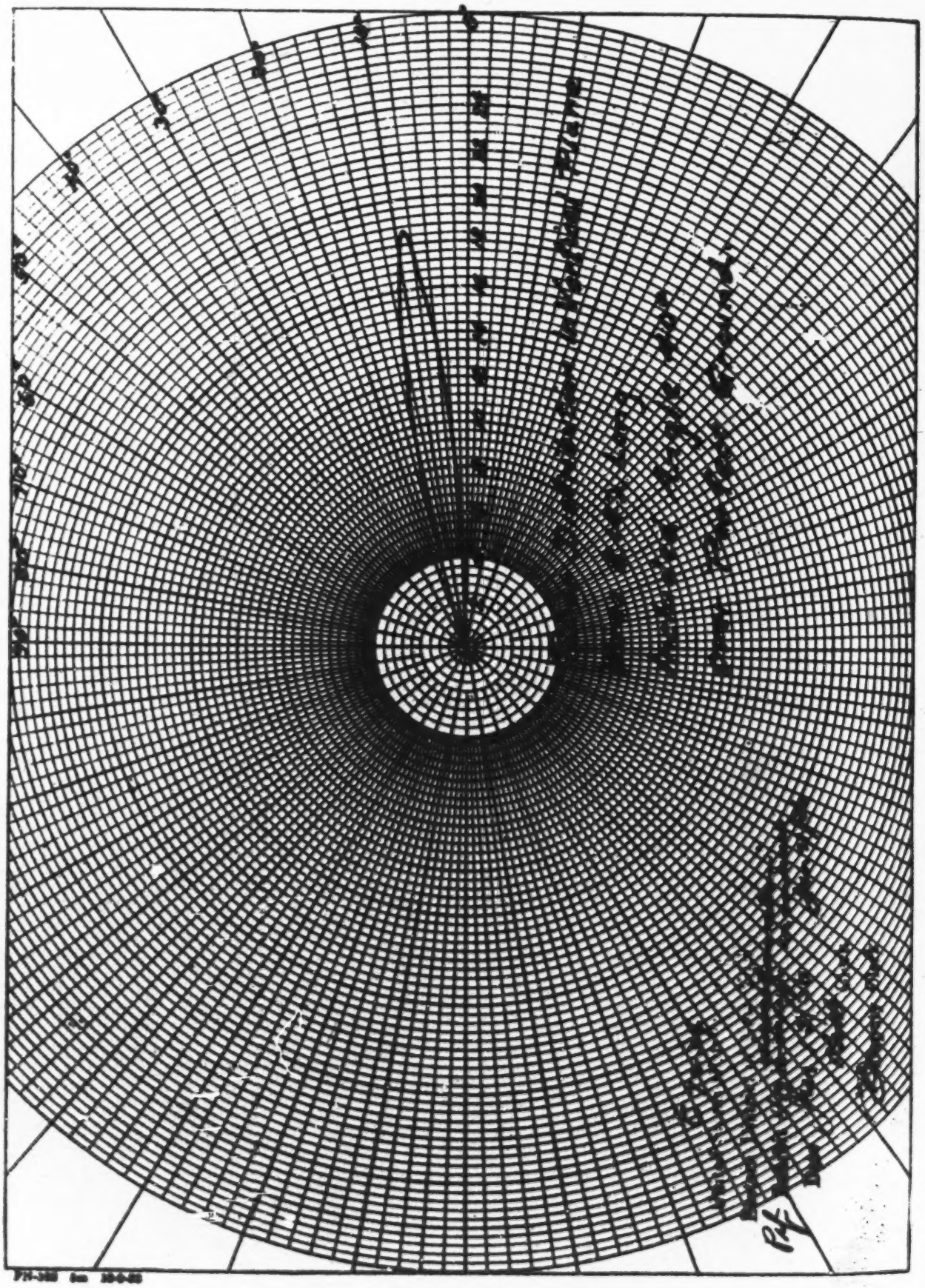


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THIS MARGIN RESERVED FOR BINDING.

IF SHEET IS READ THIS WAY (HORIZONTALLY), THIS MUST BE TOP.
IF SHEET IS READ THE OTHER WAY (VERTICALLY), THIS MUST BE LEFT-HAND SIDE.

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PATENT SPECIFICATION

392,201

Convention Date (United States): Feb. 3, 1931.

Application Date (in United Kingdom): Nov. 12, 1931. No. 31,348/31.

(Patent of Addition to No. 353,517: dated Oct. 11, 1929.)

Complete Accepted: May 12, 1933.

COMPLETE SPECIFICATION.

Improvements in Directional Antennæ.

We, STANDARD TELEPHONES AND CABLES, LIMITED, a British Company, Connaught House, Aldwych, London, W.C.2, England (Assignees of EDMOND BAUER, of 27, Buena Place, Red Bank, Monmouth County, New Jersey, United States of America, a citizen of the United States of America), do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to aerial systems and more particularly to directive antennæ of the type according to our British Patent No. 353,517.

An object of the invention is to render directive antennæ of this type capable of effective operation over a considerable range of wave lengths.

Another object is to secure a relatively high angle of reception or emanation.

An additional object of the invention is to enable such an antenna to have a sharp selectivity.

A further object is to economise in the cost of supporting structures as compared with that of previous antennæ having directional characteristics.

A still further object of the invention is to increase its selectivity against undesired horizontally projected energy.

According to the present invention, we provide a modification of the antenna claimed in our British Patent No. 353,517, characterised in this, that a substantially horizontal antenna comprises a V-shaped conductor, said conductor comprising two members each having a length substantially equal to one-half wave length of the desired wave plus the projection of the member on the vertical plane of wave propagation.

Hence in accordance with the invention an antenna is constructed by mounting a Vee-shaped conductor so that its plane lies substantially parallel with the earth and with a spacing above it at least as great as one half the wave length of the wave which is to be absorbed or radiated. The imaginary line joining the open ends of the Vee-shaped structure, in general, extend in the direction of incidence or emanation of the wave as the case may be. A similar Vee-shaped structure with its open ends closely adjacent those of the active antenna and lying in the same plane may be suitably connected thereto as a counterpoise.

Additional features and objects of the invention will be apparent from a perusal of the following specification taken in connection with the accompanying drawing in which Fig. 1 is a plan view and Fig. 2 a view in elevation of an antenna constructed in accordance with this invention. In both figures like reference numerals designate elements of similar function.

Reference numerals 1 and 2 designate the conducting members of the horizontal antenna proper each of which has a length equal substantially to one-half wave length plus the projection of the conductor on the vertical plane of wave propagation. The distant cooperating station is assumed to be included in the vertical plane containing arrows A and B, which represent the direction of desired reception or emanation, respectively. Reference numerals 3 and 4 designate conducting members of a counterpoise system, the length of each of which also equals a half-wave length of the desired wave plus the projection of the conductor on the vertical plane of wave propagation. The Vee antenna and counterpoise each resemble in structure, although having certain distinctive functional attributes, the inverted Vee antenna described in our British Patent No. 353,517. The chief point of difference and which determines its novel functional characteristics, is that the antenna described in our British Patent No. 353,517 is positioned in the vertical plane of wave propagation whereas both the antenna and counterpoise of this invention is positioned in a horizontal plane. The length of the antenna and counterpoise members are shown equal in the figure but they may differ without affecting the result obtained provided that the relation mentioned above between the

lengths of the member and its projection is maintained. By making the length of the antenna-counterpoise members equal to several, as for example, five or more wavelengths effective operation is secured over a band of frequencies inasmuch as the ratio of the projection of the member to its length for all such long antennæ may be considered substantially equal to each other.

The antenna-counterpoise system is supported by means of wooden poles 5 and insulated therefrom by means of insulators 6. The translation device 7, which may be either a transmitter or a receiver, is connected by means of transmission line 8 to the terminal of the antenna and the adjacent terminal of the counterpoise. The remaining or "back" terminals of the antenna and counterpoise are connected together through a terminating impedance 9. As shown in Fig. 2 the horizontal antenna-counterpoise system is spaced preferably a half-wave length or more above the ground. Such spacing improves the discrimination against received horizontally propagated waves.

Any type of high frequency transmission line may be suitably employed with the antenna-counterpoise system disclosed in the drawing. In practice it has been found that the form of transmission line most suitably employed depends upon whether the antenna is used as a transmitting or a receiving system. For example, when the antenna is used for transmitting purposes, a matched line which may include impedance transformers gives very satisfactory results; and when employed for receiving purposes a concentric line including a balanced coupling transformer is a suitable form. The balanced line such as is used in connection with receiving systems suppresses reradiation from the line and also to a great extent cancels interfering waves absorbed by the vertical portion of the line.

The basic theory underlying the operation of the antenna system as shown in Figs. 1 and 2 is set forth in our British Patent No. 353,517 the reception or transmission of the horizontally polarised component being assumed instead of the vertically polarised component. The counterpoise comprising conductors 3 and 4 in a sense simulates the ground associated with the vertical Vee-type antenna. Because of the compensatory effect of ground reflection substantially no reception or transmission occurs in a horizontal plane and maximum reception, as shown by arrow C, and maximum transmission, as shown by arrow D, each occur at a high angle to the plane of the antenna and the ground. Maximum reception occurs in the vertical plane including arrow A Fig. 1 and maximum transmission similarly occurs in the vertical plane including arrow B. This compensatory effect is related to the fact that the horizontally polarised component with which this invention is concerned undergoes a phase reversal on reflection. This is not true of the vertically polarised component that is made use of in the operation of the otherwise similar vertical antenna of our British Patent No. 353,517. This accounts for the difference in the angles of fire between the horizontal and vertical antennæ, a difference which would not result merely from applying the theory of said British Patent No. 353,517 assuming a 90° rotation of the antenna.

The terminating impedance 9 may be a pure resistance or a tuned circuit comprising capacity and inductance or both. If the length of each member of the antenna and counterpoise is equal to an odd multiple greater than one of a quarter-wave length, a terminating impedance equal substantially to the antenna surge impedance will produce uni-directivity; and if the length of each of these members equals an even multiple greater than two of one-quarter wave length a terminating impedance equal to the product of the antenna surge impedance and the cosine of the angle whose sides are formed by the member and its projection on the vertical plane of propagation will render the system unilateral. For antennæ having members of different length than those just mentioned a terminating impedance comprising a resistance and either a capacitive or an inductive reactance, as conditions may require, may be employed to produce a uni-lateral effect. It has been found in practice that in transmitting antennæ an iron wire resistance is suitable for dissipating the large amount of energy which would otherwise be radiated in a direction opposite to the desired direction; and in receiving systems a carbon resistance is suitable for dissipating the relatively small amount of energy received from the rear or undesired direction.

The horizontal Vee-type antenna described herein possesses distinct advantages over other types of antennæ commonly employed. First of all, as is well known in long distant radio communication, the horizontally polarised component of a radiated wave is much stronger at the receiving point than the vertically polarised component and from this viewpoint the horizontal antenna, which absorbs horizontally polarised components, absorbs a greater amount of

energy than a vertical type antenna. Moreover, since very little energy is absorbed by the horizontal antenna of the invention from horizontally propagated waves, undesired pick-up from automobiles and other interfering sources positioned at points relatively near to the receiving antenna is greatly reduced. This feature does not affect the efficiency of the antenna for receiving the desired wave since, as pointed out before, the desired wave is received at a relatively high angle with respect to the ground. In this connection it should be noted that in the case of the vertical Vee-type antenna maximum radiation and reception occur in a horizontal plane, that is, at a zero angle with respect to earth. The high angle obtained in the horizontal Vee is particularly useful in long distance transmission and reception. Still another advantage of the horizontal over the vertical type of antenna is that the horizontal type may be cheaply constructed in view of the fact that the supporting poles are relatively small.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A modification of the antenna claimed in our British Patent No. 363,517, characterised in this, that a substantially horizontal antenna comprises a V-shaped conductor, said conductor comprising two members each having a length substantially equal to one-half wave length of the desired wave plus the projection of the member on the vertical plane of wave propagation.

2. An antenna comprising two conductors positioned in a substantially horizontal plane, one conductor extending toward and the other away from a distant co-operating station, said conductors being of equal length and having a common terminal, the length of each conductor being substantially equal to one-half wave length of the desired wave plus the projection of the conductor on the vertical plane.

3. An antenna comprising two similar V-shaped conducting members as claimed in claim 1 or 2, with their open angles directed toward each other, said V-shaped members both lying in the same general horizontal plane, a transmission circuit being connected to a terminal of one V-shaped member and to the adjacent terminal of the second V-shaped member, and a terminating impedance being connected to the other terminals of the V-shaped members.

4. An antenna according to claims 1 or 2 connected to a counterpoise, said counterpoise comprising a V-shaped conductor of substantially the same dimensions and configuration as said antenna and lying in the same horizontal plane but having its open angle presented in an opposite direction.

5. An antenna arrangement substantially as described and as illustrated in the accompanying drawings.

Dated this 11th day of November, A.D. 1931.

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Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1932.

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392,201 COMPLETE SPECIFICATION 1 SHEET

[This Drawing is a reproduction of the Original on a reduced scale]

FIG. 1.

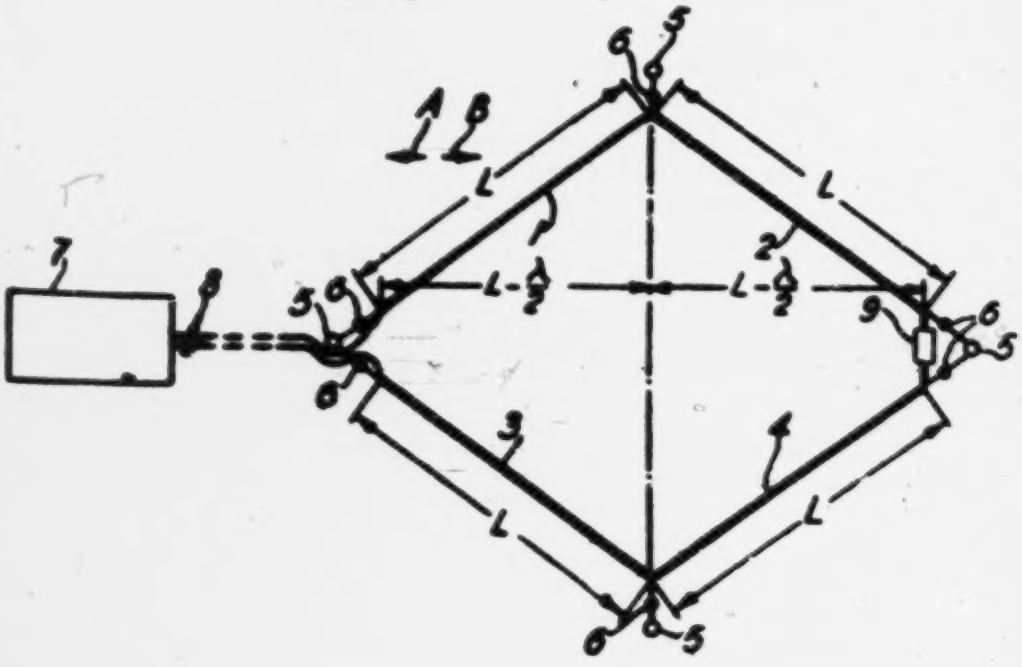
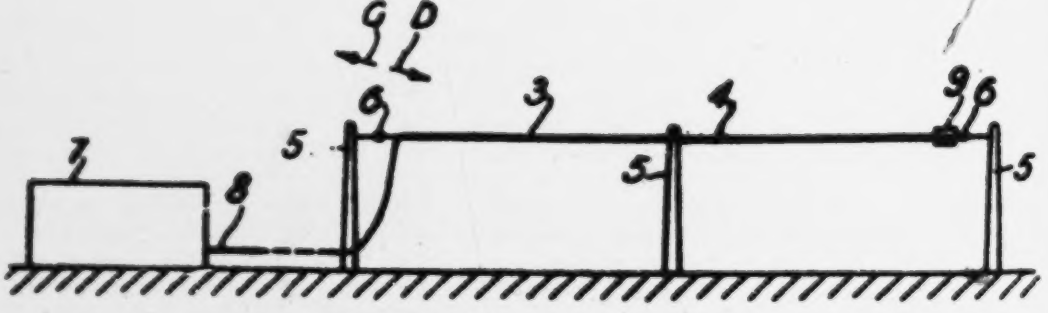


FIG. 2.



[fols. 829-842] PLAINTIFF'S EXHIBIT No. 42

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DIRECTIVE ANTENNA SYSTEM

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FIG. 1.

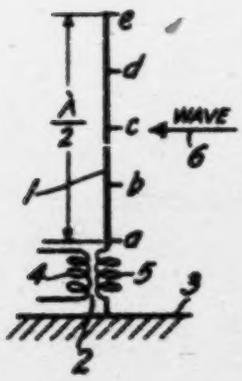


FIG. 2.

VECTOR DIAGRAM FOR ANTENNA OF FIG. 1.

SEGMENT	INDUCED VOLTAGE	CURRENT THRU RECEIVER BY DIRECT PROPAGATION	CURRENT THRU RECEIVER BY REFLECTION
e	→	←	→
d	→	↙	↘
c	→	↓	↓
b	→	↘	↙
a	→	→	←
		RESULTANT	
			

TOTAL RESULTANT

FIG. 3.

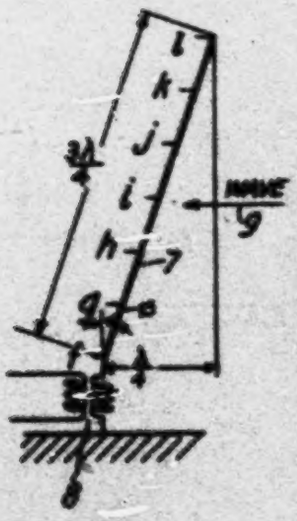


FIG. 4.

VECTOR DIAGRAM FOR ANTENNA OF FIG. 3

SEGMENT	INDUCED VOLTAGE	CURRENT THRU RECEIVER BY DIRECT PROPAGATION	CURRENT THRU RECEIVER BY REFLECTION
l	→	↑	↓
k	↘	↖	↙
j	↘	↖	↖
i	↘	←	↑
h	↘	↙	↙
g	↘	↙	↘
f	↓	↓	↓
TOTAL RESULTANT		RESULTANT	
←			

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FIG. 5.

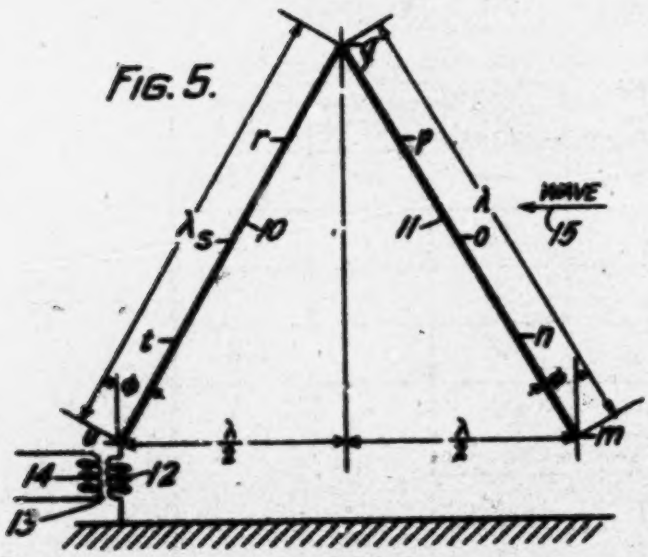


FIG. 6.

SEGMENT	u	t	s	r	q	p	o	n	m	RESULTANT
SPACE VOLTAGE	→	↗	↑	↖	↔	↙	↓	↘	→	BY DIRECT PROPAGATION
EFFECTIVE VOLTAGE	←	↙	↓	↘	→	↙	↓	↘	→	
CURRENT DISTRIBUTION: BY DIRECT PROPAGATION	←	↖	↑	↗	→	↖	↑	↗	→	BY REFLECTION
CURRENT DISTRIBUTION: BY REFLECTION	→	↖	↓	↗	→	↖	↓	↗	←	

FIG. 7.

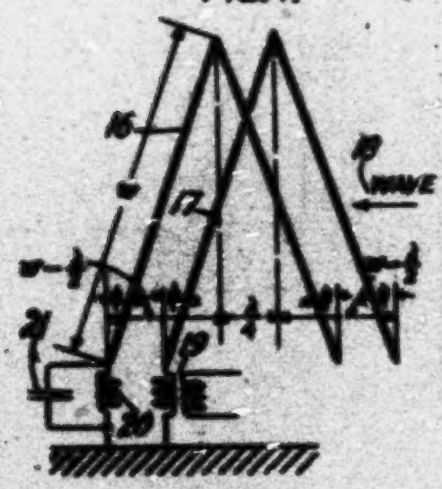
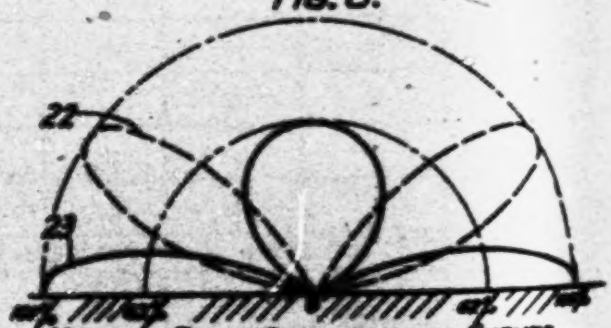


FIG. 8.



VERTICAL PLANE CHARACTERISTIC CURVES

w = λ

— φ = 0°

— φ = 30°

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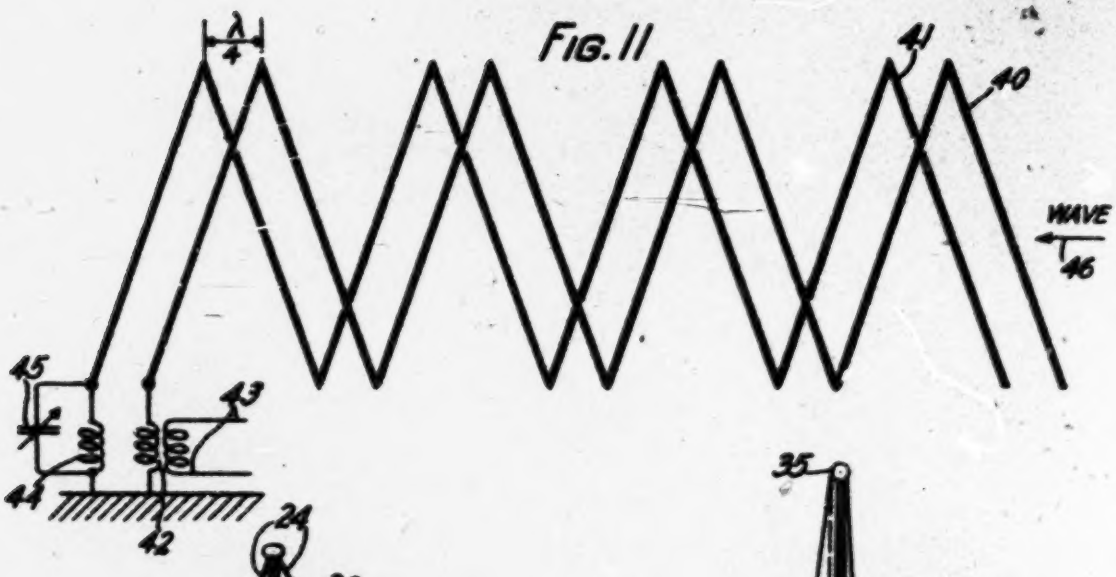
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FIG. 11



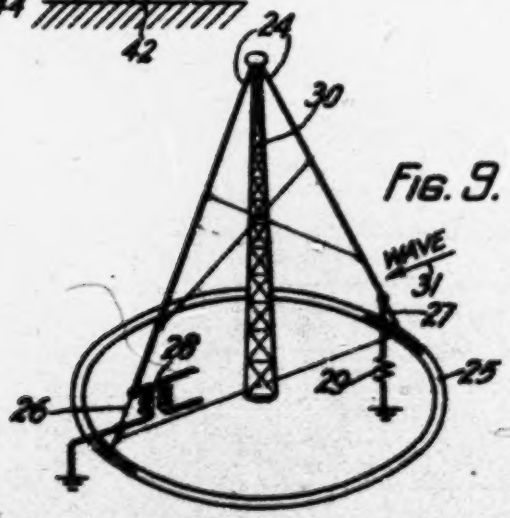


FIG. 9.

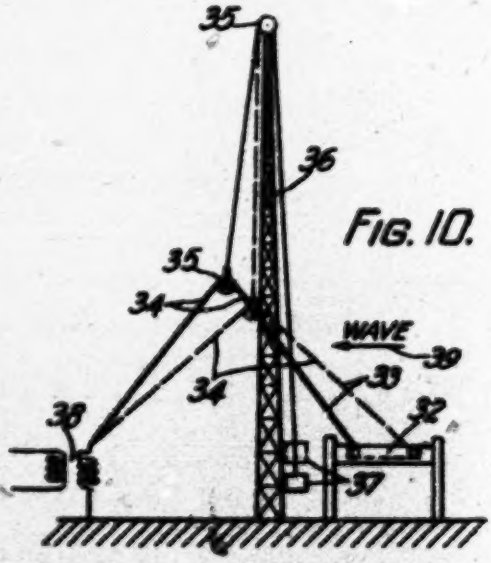


FIG. 10.

FIG. 12.

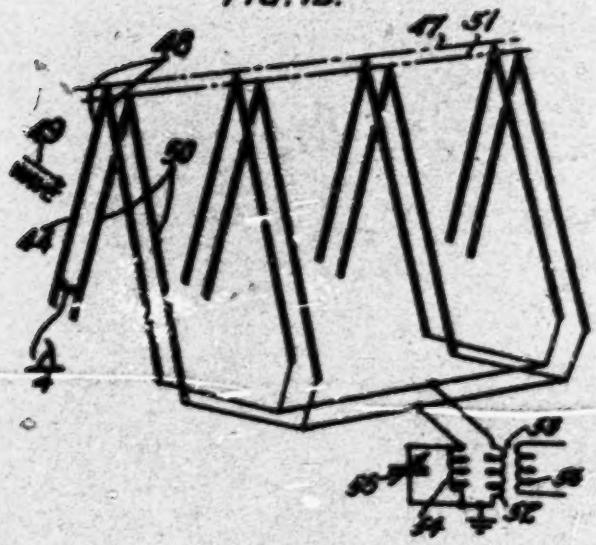
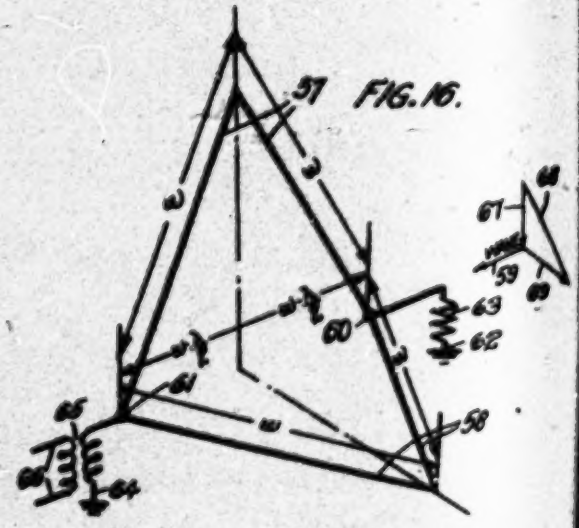


FIG. 16.



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Fig. 13.

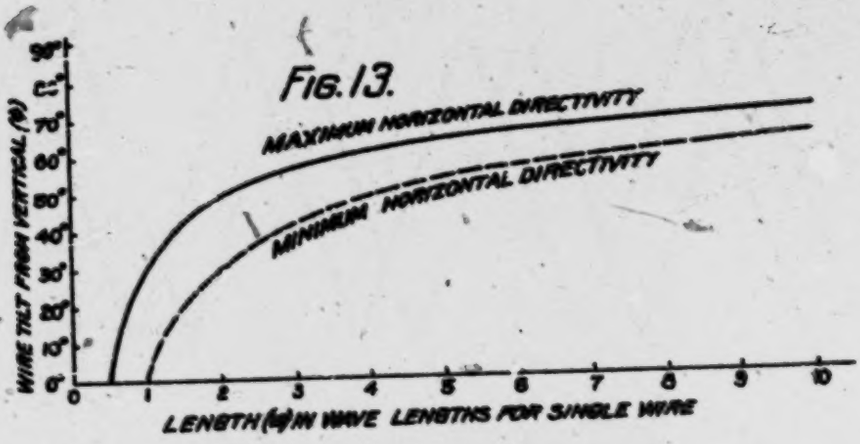


Fig. 14.

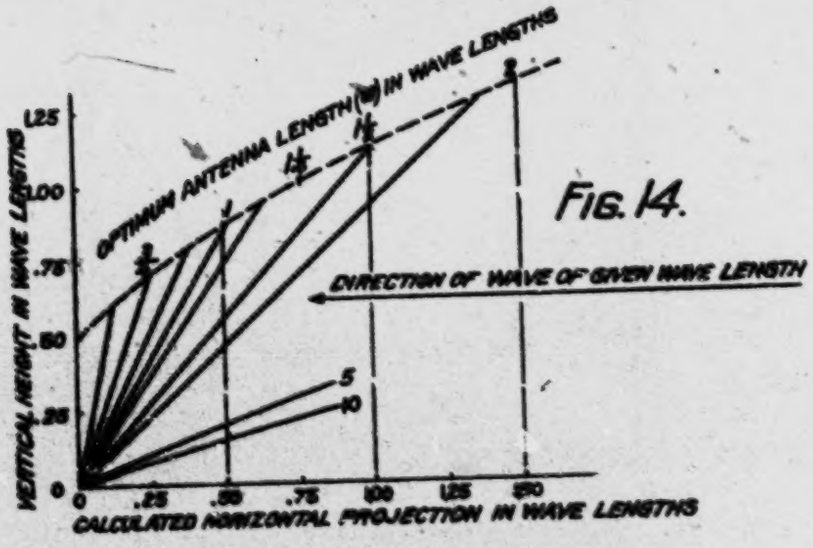
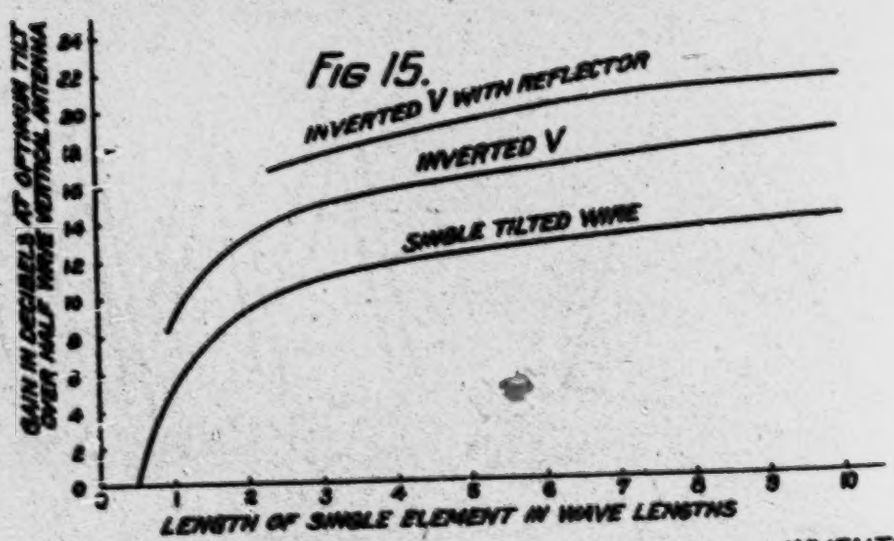


Fig 15.



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Patented Feb. 28, 1933 1,899,416

UNITED STATES PATENT OFFICE

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DIRECTIVE ANTENNA SYSTEM

Application filed October 11, 1929. Serial No. 398,980.

This invention relates to aerial systems, and more particularly to directive antennæ for use in such systems.

An object of the invention is to render a directive antenna capable of effective operation over a considerable range of wave lengths. Another object of the invention is to increase the receiving effectiveness of an antenna. An additional object of the invention is to enable an antenna to have a desirably sharp selectivity both in a vertical plane and in a horizontal plane. A still further object is the reduction of fading in wave propegation.

It is well known that the most effective height for a simple vertical antenna with a ground connection at its lower end is one-half the wave length of the waves transmitted. This is because the elemental lengths of such an antenna absorb or emit, as the case may be, energies which conspire when superposed to yield a resultant that is greater in magnitude than may be had from a similarly excited similar antenna of shorter or longer length. It has been found, however, that the receiving effectiveness which is characteristic of a vertical half-wave length antenna may be retained and in fact enhanced by an increase in the length of the antenna accompanied by a definite tilt of the antenna toward or away from the remote cooperating sending station. The simple general rule is that the length of the tilted antenna should be equivalent to a half-wave length of the transmitted waves plus a length equal to the projection of the antenna on a plane parallel to the direction of the wave propagation. In the case of horizontally propagated waves and perfect ground, the length of the antenna should be equal to a half-wave length increased by the horizontal projection of the tilted antenna. If the ground is imperfect the length will be slightly different from the above.

It results also that in the case of a tilted antenna several wave lengths long, the effective response of the antenna varies but little with a considerable change in wave length of the transmitted waves, assuming that the energy of the transmitted waves and their direction of propagation remain unchanged. It is accordingly feasible to employ such an antenna in a system in which it is desirable or necessary to change wave lengths from time to time and this is an extremely important feature of the invention. It is also practical to combine the antenna with simple mechanical means for quickly changing the antenna tilt to the optimum angle simultaneously with a change in the wave length since, by this expedient, accommodation to different wave lengths of received waves may be achieved without change in length of the antenna or substitution of one antenna for another; and to combine the antenna with mechanical means for rotating the vertical plane of the antenna to the optimum position for radiating or absorbing energy.

Tilted antennæ constructed according to this invention readily lend themselves to various combinations and to use in arrays. Such an antenna suitably terminated exhibits a back-end effect which is relatively very small in comparison with its end-on directive selectivity.

Additional features of the invention and ends which it attains will be apparent from a perusal of the following specification taken in connection with the accompanying drawings in which;

Fig. 1 represents a vertical half-wave length antenna shown here merely for the purpose of explaining an incidental feature of the invention, Fig. 2 being a table showing in detail the vector currents for the antenna of Fig. 1;

Fig. 3 represents a three-quarter wave length antenna tilted at the optimum angle toward the incoming wave, Fig. 4 being a vector diagram for this antenna;

Fig. 5 illustrates an inverted V-type antenna comprising two tilted conductors or elements, Fig. 6 representing a vector diagram for such a system;

Fig. 7 is a double inverted V antenna comprising two single V-type antennæ;

Fig. 8 shows the vertical plane directional characteristic of a tilted single wire antenna and a vertical single wire antenna each one wave length long;

Fig. 9 represents schematically one system for combining an inverted V antenna section with means for rotating the vertical plane of the antenna to any desired direction;

Fig. 10 shows a single inverted V antenna section associated with means for changing the angle of tilt of each leg or element of the V section;

Figs. 11 and 12 represent, respectively, a unidirectional "end-on" and a unidirectional "broadside" antenna system each comprising an exciter and a reflector;

Figs. 13, 14 and 15 are curves for systems which employ the invention and are designed for a particular wave length. The curves in Fig. 13 show the relation between the angle of tilt of a single linear wire antenna and the length of the antenna in the cases of maximum and minimum horizontal directivity; the curve of Fig. 14 furnishes a means of determining the horizontal and vertical projections of different length antennæ, each tilted at the optimum angle for horizontal directivity; and the curves in Fig. 15 show the gain in decibels realized in using tilted antenna of the types and lengths indicated as compared to the results obtained with the half-wave vertical antenna; and

Fig. 16 illustrates two inverted V-sections positioned in different planes and having common terminals.

Referring to Fig. 1, the reference numeral 1 designates a vertical half-wave length antenna which is associated with a radio translation device, such as a receiver or transmitter, by means of transformer 2 having windings 4 and 5. The lower terminal of the antenna is connected through winding 5 to the ground 3.

Assuming the direction of the incoming wave to be as shown by the arrow 6 the wave impinges on all elements such as *a*, *b*, *c*, *d* and *e* of the vertical antenna 1 at the same instant and therefore the various induced voltages are in phase with each other and may be assumed to have the directions indicated in the second column of Fig. 2. The current produced by the voltage in segment *e* and directly propagated to winding 5 will require a time corresponding to a half cycle to travel from segment *e* to the coil 5. Similarly, the current directly propagated from point *d* will require a time corresponding to three-eighths of a cycle to reach winding 5 and currents directly propagated from points *c*, *b* and *a* will require a time corresponding to one-fourth, one-eighth and zero cycles, respectively, in arriving at winding 5. Assuming counter-clockwise rotation as positive or advancing the individual currents in winding 5, at the instant under consideration, are consequently retarded in respect to their producing voltages by an amount equivalent to the antenna length separating winding 5 from the respective segments. In column three of the table of Fig. 2 this is represented by means of small arrows which indicate direction only, and not current magnitudes. Summing up the individual vector currents directly propagated, it will be seen from the diagram at the bottom of the column of the table that the resultant is a maximum vector inasmuch as it is a diameter of the vector circle. Although this proof is based on a choice of spaced elemental portions, it is evident that the conditions in the antenna as a whole are fairly represented by such portions and therefore that the table indicates the resultant effect in the antenna as a whole.

The resultant reflected current is similarly determined. The conditions are as indicated in column four of the table. Current from the segment *e* has a reversal of phase on account of reflection from the open-ended antenna and therefore arrives at winding 5 at a time corresponding effectively to a full cycle after it originates and therefore, at any given instant, as measured at winding 5 it is retarded a full cycle in respect to the voltage *e*. Reflected current occasioned by voltage *d* travels an eighth of a cycle to the open end, is effectively retarded a half-cycle by reflection and then is retarded, by the half-wave antenna, another half-cycle before reaching coil 5. At the instant it arrives at winding 5 it is therefore retarded one and one-eighth cycles in respect to the voltage in segment *d*. The remaining vectors for the reflected currents are determined in a similar manner and their resultant is also a diameter of the vector circle as shown in the table. This last mentioned resultant, it will be observed, has the same direction as the resultant for the directly-propagated current and consequently, both resultants for the antenna of Fig. 1 add or cooperate to give a maximum total resultant or, in other words, maximum horizontal directivity. The vectors are, of course, rotating and the directions shown by the arrows are relative only.

In connection with Fig. 1 it should be noted that if the vertical antenna were one wave length in height instead of one-half wave length, a minimum or zero total vector resultant would be obtained for waves propagated in a horizontal plane. A vertical antenna one wave length in height is therefore especially adapted to reject horizontal waves. Also, in comparing vertical antennæ and tilted antennæ constructed in accordance with the invention, a vertical half-wave antenna is a suitable standard of comparison inasmuch as it possesses a maximum horizontal directional characteristic.

In Fig. 3 the antenna 7 is three-quarters of a wave length long and is connected through one winding of transformer 8 to ground. The other winding of transformer 8 may be connected to a transmitter or receiver but for purposes of this description it

will be considered as connected to a receiver. The antenna is tilted from the vertical at such an angle ϕ that the projection of the antenna on a plane parallel to the direction of the incoming wave, represented by the arrow 9, is one-half wave length shorter than the length of the antenna proper, that is, one-quarter wave length long for the antenna of Fig. 3. As explained vectorially below an antenna tilted at such an angle, termed herein the optimum angle for the given antenna length, possesses a maximum directional characteristic in the direction of the wave propogation. The small letters *f*, *g*, *h*, *i*, *j*, *k* and *l* represent small antenna segments spaced an eighth wave length along the antennæ.

Referring to the table of Fig. 4, and to the induced voltage column particularly, it will be seen that the voltages simultaneously induced in the segments are of relatively different phase and in this respect the system differs from that shown in Fig. 1. This results from the fact that the part of the wave inducing the voltage in any one segment is 15° or $\frac{1}{24}$ of a cycle retarded in respect to that inducing the voltage in the segment immediately above. The various phase difference between the induced elemental voltages and their resulting currents through the transformer 8 are obtained in the manner already explained in connection with Fig. 2, the currents, as in Fig. 1, being always retarded in respect to their voltages with the exception of the current directly propagated from the lowest segment. A maximum resultant is obtained for the directly-propagated current and zero resultant for the reflected current as shown at the bottom of the table of Fig. 4.

In all antennæ tilted in accordance with this invention, the resultant of the directly-propagated current is a diameter of a vector circle. The resultant of the reflected current varies from zero, in the case of antennæ having a length equal to an odd quarter multiple of a wave length, to small values when the length is an even multiple of a quarter wave length; and as the even multiple increases the reflection resultant decreases. An antenna tilted as shown in Fig. 3 has a substantially unity front to back-end ratio which may be greatly increased, that is, the effects produced by waves propagated in a direction opposite to that indicated by arrow 9 may be practically eliminated by properly terminating the antenna. It has been found, for example, that if the single wire antenna is equal in length to an odd multiple, greater than one, of a quarter wave length, a terminating impedance equal substantially to the antenna surge impedance will produce unidirectivity; and, if the antenna length equals an even multiple, greater than two, of a quarter wave length, a terminating impedance equal to the product of the antenna surge impedance and the sine of the angle of tilt of the antenna from the path of propagation will render the system unilateral. The terminations, however, would not affect the reflection phenomena and would not change the characteristic illustrated in Fig. 4 since, for single wire tilted antennæ the resultant reflected current is zero as indicated in this figure. Stated differently, if the tilted antenna has a length equal to an odd multiple of a quarter wave length, and is terminated in an impedance equal to its surge impedance, the ratio of the front to back end reception or radiation is infinity. If it has a length equal to an even multiple of a quarter wave length and is similarly terminated, the ratio is small but this ratio increases as the length, that is, as the even multiple, increases and by changing the terminating impedance to a value equal to the product of the surge impedance and the sine of the angle of tilt, the ratio may be made infinite.

Compared to the standard half-wave antenna of Fig. 1 the transmission gain obtained in using the antenna of Fig. 3 results primarily from the fact that the latter is longer and more directive than the former. The vertical antenna receives horizontally propagated waves equally from all directions whereas the tilted antenna favors two opposite directions, the directivity diagram resembling a figure eight. Compared to a vertical three-quarter wave length antenna the final resultant for the tilted antenna of Fig. 3 possesses no reflected component whereas the resultant for the vertical antenna includes a reflected as well as a directly-propagated component.

In both Figs. 2 and 4 the directly-propagated and reflected current vectors for the extreme top segment are opposite in phase to those for the extreme bottom element. This condition is necessary in all cases for maximum results. In other words, the antenna should be tilted toward or away from the incoming wave in such a manner that current originating at the top element will arrive or pass through the receiver a half-cycle later than that simultaneously originating in the bottom element. When this condition is fulfilled the antenna will be a half-wave longer than its projection on a plane parallel to the direction of the wave propagation and its angle with the projection will be the optimum one as heretofore defined.

In Fig. 5 another embodiment of the invention is shown comprising two conductors 10 and 11 each tilted at the optimum angle ϕ for the desired waves and joined to each other so as to form an inverted V. For purposes of illustration the length of each conductor or element has been made equal to one wave length. As in Fig. 3, this length is a

half-wave length longer than the projection of the element on a plane parallel to the direction of the propagation of the desired waves. The lower terminal of conductor 10 is connected to ground through winding 12 of transformer 13. Winding 14 of this transformer is connected to either a transmitter or a receiver. The antenna system shown in this figure possesses a bidirectional characteristic but it may be made unidirectional by properly connecting the conductor 11 to ground through an impedance at "m". The small letters *m* to *u* designate infinitesimal segments located along conductors 10 and 11, the adjacent segments being a quarter-wave length apart. The arrow 15 indicates the direction of the incoming wave.

Referring to Fig. 6 a vector diagram for the structure shown in Fig. 5 is shown. The induced or spaced voltages at the elemental segments *m* to *u* are represented in the top row of arrows. As shown in this row of arrows, the voltage induced in segment *n* is one-eighth of a cycle retarded over that induced in segment *m* and similarly the voltages induced in the remaining elemental segments are one-eighth of a cycle behind that induced in the segment immediately adjacent at the right. The second row of arrows from the top represent the effective or wire voltages at the same elemental points. The effective (as regards the effect on winding 12) voltages present in conductor 10 as, for example, in segments *p* to *u* are opposite in phase to those induced in conductor 10 and cooperate with, rather than oppose, the effective voltages in the other of the two conductors. This is true since, so far as concerns their joint effect in winding 12, the direction of the elemental voltages in conductor 10 are reversed with respect to the voltages in conductor 11 by the bend or apex of the antenna.

The manner of determining the phase relation between the voltages and both the directly-propagated and the reflected currents passing through winding 12 has been described in connection with Figs. 1 and 2 and will be outlined only briefly here. The directly-propagated current produced by voltage *m* will arrive at coil 12 two complete cycles behind the elemental voltage *m* producing it, inasmuch as the antenna is two wave lengths long. Current resulting from voltage *n* travels a distance equal to one and three-fourth wave lengths along conductors 11 and 10 and of course passes through winding 12 one and three-quarter cycles behind voltage *n*. Similarly the direction of the other elemental directly-propagated and reflected currents may be determined bearing in mind that current flowing to the open end is reversed on reflection and therefore effectively retarded a half-cycle. For example, reflected current travelling from *n* arrives at winding 12 in opposite phase relation to the directly-propagated current; and current originating at *n* travels one-fourth of a wave length, corresponding to a retardation of 90°, to the free end, is retarded 180° by reflection and then travels two full wave lengths corresponding to a retardation of 720°, to coil 12. The summations of both the direct and reflected currents are shown at the right of the table in Fig. 6. It should be observed in regard to the reflected current that the resultant for each of conductors 10 and 11 for progressively increasing numbers of segments travels 540° or one and one-half times around the vector circle and finally assumes the same direction as the resultant for the other conductor. This double resultant is added to the double resultant obtained for the directly-propagated current to give the total resultant shown at the extreme right in Fig. 6. For waves propagated in a direction opposite to that shown in this figure the direct and reflected components will be similar but opposite in direction to the reflected and direct components, respectively, shown in the figure. The total resultant will, of course, also be opposite in direction to that shown in the figure. The system of Fig. 5 is therefore bilaterally directive and equally responsive to waves propagated in both directions.

In Fig. 7 a unidirectional receiving system is shown comprising two inverted V antennæ 16 and 17. Antenna 16, the reflector, is spaced one-fourth of a wave length farther away from the wave source and in the same vertical plane as antenna 17, the exciter. The arrow 18 indicates the direction of the wave propagation. Each tilted conductor or element has a length "a" wave lengths long and is positioned at the optimum angle ϕ for horizontal directivity so that the horizontal projection of each element is a half-wave length shorter than the element length or $a - \frac{\lambda}{2}$ wave lengths. Reference numeral 19 represents a transformer utilized for connecting the exciter 17 to the receiver. Numerals 20 and 21 refer, respectively, to an inductance coil and a condenser employed for properly terminating the reflector 16.

Unidirectivity is achieved by means of the reflector in a manner which is familiar to those skilled in the art. The voltage induced in conductor 16 by the desired waves is retarded one-fourth of a cycle in respect to that induced in conductor 17. Since the field reradiated from conductor 16 is opposite in phase to that of the space field immediately adjacent and, since there is a quarter-wave length spacing between the reflector and exciter, energy from the inverted V antenna 16 induces a voltage in antenna 17 in phase with the voltage induced in the latter. The resulting currents therefore in-

sist each other and reception in this direction is a maximum. Waves from the opposite direction, however, induce a voltage in the reflector 16 which leads that simultaneously induced in the exciter 17 by a quarter cycle. Because of the 180° phase change due to reradiation and the quarter-wave length spacing, the voltage induced in the exciter 17 by energy from the reflector 16 is opposite in phase to that then being induced in the exciter. Currents induced by energy from this undesired direction are therefore effectively suppressed.

In Fig. 8 polar directional characteristic curves in the vertical plane which have been mathematically calculated are shown for a linear receiving antenna having a length equal to one wave length and connected to a perfect ground. The dotted line curve 22 containing two loops represents the characteristic when the antenna is vertically positioned and the full line curve 23 when the antenna is tilted 30° from the vertical in a vertical plane which includes the point of propagation. Along the horizontal axis the distance designated one hundred per cent represents the maximum desired current obtainable theoretically for this system. When the antenna is tilted in any other vertical plane the desired current will be less than the maximum just mentioned. A study of these curves reveals the fact that there is practically no reception in the horizontal direction when this antenna is in vertical position whereas when it is tilted 30° in the path of the incoming wave, there is a maximum reception of desired waves. Furthermore, the position of the minor lobe for the tilted antenna indicates that this antenna has a very good characteristic for waves propagated vertically as well as horizontally. In other words it has a high angle of response and therefore is particularly adapted for minimizing static if static is more intense at angles relatively close to the earth's surface as it is believed to be. For the same reason the absorbed energy including that reflected by the Heaviside layer arrives over comparatively few transmission paths with the result that fading is materially reduced. The antenna represented possesses a bidirectional characteristic but as explained heretofore it may be made unidirectional by either the use of a reflector or a proper terminating impedance.

In Fig. 9 an inverted V type antenna 24 such as heretofore described is shown arranged so that the vertical plane of the antenna may be changed to any desired direction. The particular arrangement shown in this figure is illustrative only, and it should be understood that any suitable scheme for changing the direction of the vertical plane so as to include therein a distant transmitting or receiving station could be utilized in place of the rotating means shown here.

The system schematically shown in this figure comprises a circular track 25 located in a horizontal plane and connected through insulators 26 and 27 to both lower terminals of the inverted V. One terminal is grounded through one winding of transformer 28 which is associated with a translation system such as a transmitter or receiver. The other terminal is connected through a terminating impedance 29 to ground for the purpose of obtaining a unidirectional characteristic. The plane of the antenna may be rotated about the supporting tower 30 in either direction, the antenna conductors being kept in the same plane by means of suitable guy wires as shown. The antenna proper functions the same as the one shown in Fig. 5 and in addition thereto it is unidirectional and adjustable to the optimum plane for transmission or reception. It is shown in the drawings in the optimum position for receiving waves propagated in the direction indicated by the arrow 31.

In Fig. 10 one scheme of adjusting or changing the tilt of the antenna to the optimum angle ϕ for transmitting or receiving waves of any given wave length within certain limits is illustrated. The reference number 32 represents a horizontal track suitably supported and along which the conductor or element 33 of the inverted V type antenna 34 may be moved. The antenna is supported by a pulley 35 which in turn is supported by a pole or tower 36 and connected to a counterweight 37 so that when the conductor moves from the position shown by the full line to the position shown by the dotted line the combination of the pulley and counterweight cooperate to maintain each element of the antenna 34 equal in length and the angle of tilt of each element equal to that of the other. The antenna is connected to ground through transformer 38 which is connected to a receiver for receiving waves from the direction shown by the arrow 39. A transmitter could, of course, be used on this system in place of the receiver. If each side of the inverted V is several wave lengths long the apex of the V moves through a comparatively small distance as will be evident from the description given below of the curve of Fig. 13. The scheme used in Fig. 10 could of course be combined with that used in Fig. 9 so that an antenna system could be constructed which would be adjustable to different optimum angles and at the same time capable of being rotated to any desired direction for maximum directivity. Such a system would be especially suitable for use on boats and aircraft and in places where it is impractical to construct an antenna such as shown in Figs. 11 and 12 to be described.

Figs. 11 and 12 illustrate, respectively, an

"end-on" and a "broadside" antenna array of inverted V type antenna units of the invention. The "end-on" array and transmission system shown schematically in Fig. 11 comprises an exciter 40 and a reflector 41 each of which in turn comprises four inverted V sections, constructed in accordance with the invention and connected electrically to each other as shown. Practically any number of sections may be utilized, the number illustrated being arbitrarily chosen. Both the exciter and reflector are arranged in the same vertical plane with each other and with the distant cooperating station, and each reflector section is one-quarter of a wave length farther away from the distant station than its corresponding exciter section. The exciter is conductively connected through a transformer 42 to ground and inductively associated with a transmission line 43 to a translation device. The deflector is grounded through an impedance comprising coil 44 and condenser 45. The arrow 46 indicates the direction of the wave. The system shown in Fig. 11 is particularly suitable for use where considerations of ground space are not of primary importance. It possesses a very sharp unidirectional characteristic which may be greatly improved by properly choosing the number of the sections or inverted V antennæ.

In Fig. 12 a broadside antenna arrangement is schematically shown in perspective. It comprises an exciter row 47 of inverted V sections, such as 48, all the apexes of which are in a plane perpendicular to the direction of the wave propagation, represented by the arrow 49. The sections are spaced from each other the proper distance which, for a given number of sections, will produce the sharpest unidirectional characteristic. In the same plane with each exciter section and one-quarter of a wave length farther away from the distant station is another inverted V type section, such as 50. These sections form a row 51 which comprises the reflector. Both the exciter and the reflector may consist of any number of sections and are not intended to be limited to the number shown on the drawing.

The transmission system shown in Fig. 12 is designed so that current flowing from each of the exciter sections to the winding 52 of transformer 53 traverses a distance equal to that which is traversed by currents flowing from the remaining exciter sections. Similarly, in the transmission system shown associated with the reflector sections, the current flowing from each reflector section to ground through the terminating impedance comprising coil 54 and condenser 55 traverses a distance equal to that traversed by the current flowing from the other reflector sections. The transmission system therefore does not affect the phase relation between the currents of the various sections. Winding 56 of transformer 53 is connected to a receiver.

The operation of the system shown in Figs. 11 and 12 is similar to that of the well known end-on and broadside arrays, respectively. When the end-on system is used for receiving purposes the energy absorbed in each section is serially combined with that absorbed in the other sections, and certain sections serve as a transmission line for energy absorbed in other sections. When the broadside array of Fig. 12 is used for receiving purposes the corresponding elements are simultaneously energized by the incoming wave and the sections are in a sense parallel to each other. A more detailed description of the end-on and broadside systems may be found in the applicant's copending applications Serial No. 173,833, filed March 9, 1927 and Serial No. 235,464, filed November 25, 1927, respectively. In both systems the vector resultant for each section effective at the transformer possesses the same direction as the other sections. Both systems may, of course, be employed for transmitting purposes with the same degree of success.

Referring to Fig. 13 two curves are shown, one of which serves as a means of determining the tilt from the vertical in the vertical plane including the distant station for different lengths of a linear antenna for the condition of maximum horizontal directivity and the other of which similarly determines the tilt for minimum horizontal directivity. Both curves possess a relatively flat characteristic for antenna lengths greater than five wave lengths. An examination of the curve for maximum horizontal directivity shows that the angle of tilt for an antenna five wave lengths long is 64° approximately and one ten wave lengths long is 72° approximately. Because of this small difference of 8° approximately, it is apparent that an antenna five wave lengths long and tilted the mean of the above optimum angles that is, 68°, toward the incoming wave would be suitable for use over a frequency range in which the high frequency is double that of the low. These curves therefore disclose one of the important features of the invention, namely, that a tilted antenna is particularly well adapted for use over a comparatively large frequency range. Also, it may be seen from a comparison of the two curves that an antenna tilted for maximum horizontal directivity may easily be adapted for minimum horizontal directivity because of the small difference, for an antenna of given length, between the optimum angles for maximum and minimum directivity.

From the curves in Fig. 14 the horizontal and vertical projections of antennæ tilted at various optimum angles may easily be determined. The curve also illustrates in an-

other way the fact that for every antenna above five wave lengths long there is little difference in the various optimum angles and that an antenna several wave lengths long and tilted in accordance with the invention is admirably suited for use for several different frequencies.

From the curves in Fig. 15 the gain realized in using a single tilted wire, an inverted V antenna, and a double inverted V antenna of various lengths over the standard half-wave vertical antenna may be determined. As pointed out before, part of the gain obtained is due to the increased length employed in the tilted antenna as compared to the vertical half-wave standard and part is due to the fact that the antenna radiation resistance is decreased through the sharper directivity. Curves for the different types of arrays illustrated in Figs. 11 and 12 have been omitted from the drawing. It is sufficient to say that such arrays obviously possess greater transmission gains than that of the single sections whose gain over the standard are shown in Fig. 15.

In Fig. 16, two inverted V-sections 57 and 58 each constructed in accordance with the invention, are illustrated, one being disposed in a vertical plane and the other in a horizontal plane. The two sections are joined at the common extremities or terminals 60 and 61. The length s of each leg of the antenna is a half wave length longer than the projection of the leg on the path of the wave propagation designated by numeral 59. Extremity 60 is connected to ground 62 through a terminating impedance 63 which, as explained above, is of such value as to render the system unilateral and which, as also explained above, in certain cases only is equal to the surge impedance of the antenna. The other terminal 61 is connected to ground 64 through the primary winding of transformer 65, the secondary of which is associated by means of line 66 with a receiver not shown on the drawings.

The operation of the system shown in Fig. 16 is apparent in view of the discussion given above with respect to the previously described figures. It should be noted, however, that the antennæ 57 and 58 favor different components of the same wave. Antenna 57, for example, absorbs a maximum amount of energy from the vertical component 67 of the polarized wave 68 and substantially no energy from the horizontal component 69. On the other hand, antenna 58 absorbs a maximum amount of energy from the horizontal component 69 and little, if any, energy from the vertical component 67. Obviously the two antennæ may be used jointly, as illustrated, or separately.

While the invention has been described in connection with certain specific embodiments it is clear that the invention may be suitably employed in many other embodiments, and it is not intended to limit the invention to those illustrated. For example, arrays comprising single tilted conductors such as illustrated in Fig. 3, and other double inverted V systems comprising a plurality of inverted V antennæ lying in different planes with their apexes or extremities superimposed may well be employed.

What is claimed is:

1. An antenna comprising a conductor positioned at an angle greater than zero degrees and less than ninety degrees to a plane perpendicularly related to the path of propagation of a wave and having a length substantially equal to a half-wave length of the desired wave plus the projection of the antenna on the path of the propagated wave.

2. A directive antenna system comprising one or more linear conductors at least one of which is inclined with respect to the vertical and is equal in length to substantially a half-wave length of the desired waves plus its projection on the path of the said waves.

3. A transmitting antenna comprising a conductor inclined to the vertical to such a degree that its projection on the horizontal is substantially equal to a multiple of one wave length.

4. A radio antenna comprising a conductor inclined to the vertical to such a degree that its projection on the horizontal is substantially equivalent to one wave length, the antenna having a linear dimension substantially equal to a multiple of a half wave length.

5. An antenna comprising a tilted conductor having a length substantially equal to a half wave length of the desired waves plus the projection of the antenna in the path of the waves, a receiver connected to one terminal and a suitable terminating impedance connected to the other terminal of the antenna.

6. A directive antenna for receiving a plurality of desired waves comprising a tilted conductor having a length of the order of five to ten wave lengths of the longest desired wave and tilted in the plane of wave propagation at an angle of the order of 18° to 25° from the path of propagation.

7. A tilted antenna for receiving a plurality of waves having a length greater than substantially five wave lengths of the longest desired wave and tilted in the plane of wave propagation at an angle less than 25° from the path of propagation so that the radiant energies of various wave lengths within a desired range which are absorbed by its terminal segments yield oppositely directed effects substantially when one of the energies is superimposed upon the other, and a translation device associated with the antenna.

8. An antenna comprising two conductors each positioned at an angle greater than zero

degrees to the plane of polarization and each having a length equal to a half-wave length of the desired waves plus its projection in the path of the wave propagation, the uppermost terminals of said conductors being joined.

9. A V-shaped antenna section comprising one conductor tilted toward and another conductor tilted away from the incoming wave, said conductors being of equal length and having a common terminal, said length being substantially equal to a half-wave length of the desired wave plus the projection of the conductor in the path of the waves, and a translation device associated with said section at a conductor terminal thereof.

10. An inverted V-shaped antenna section comprising one conductor tilted toward and another conductor tilted away from the incoming wave, said conductors being of equal length and joined at the top, said length being substantially equal to a half-wave length of the desired wave plus the projection of the conductor in the path of the waves, a receiver connected to the lower terminal of one conductor, and a suitable terminating impedance connected to the lower terminal of the other conductor.

11. A directive antenna system comprising a plurality of V-shaped sections lying in the same plane with each other and with a distant cooperating station, one of the said sections being an odd multiple of a quarter wave length of the desired wave farther away from said distant station than the other of the said sections.

12. A double inverted V-antenna system comprising an inverted V-shaped exciter and an inverted V-shaped reflector, each comprising conductors tilted for maximum directivity, said exciter and reflector being in the same plane with each other and with the path of the desired incoming waves, the reflector being a quarter wave length farther away from the source of said waves than the exciter, a receiver connected to the exciter, and an impedance connected to the reflector.

13. A directive antenna system comprising a plurality of inverted V-shaped sections comprising conductors each positioned at an acute angle to the plane of polarization of the desired wave and each having a length equal to a half-wave length of the desired wave plus its projection on the path of wave propagation, said sections lying in different planes and having common terminals.

14. In combination, an inverted V-shaped antenna comprising tilted conductors, each having a length equal to a half wave length of the desired wave plus its projection on the path of wave propagation, said antenna being rotatably supported at its apex, and one terminal of said antenna being connected to a translation device and the other terminal to a terminating impedance.

15. In combination with one or more inverted V-shaped antenna sections each comprising oppositely tilted conductors, the length of each of which is equal to a half wave length of a desired wave plus the conductor projection on the path of said wave, means for changing the plane of the antenna section to any desired direction.

16. In combination with an inverted V-shaped antenna, means for changing the tilt of each conductor thereof an equal amount, the tilt of each conductor of the antenna being adjusted so that the difference between its length and its projection on the path of a desired wave equals substantially a half wave length of said wave.

17. In combination, an inverted V-shaped antenna the apex of which is adjustably supported and one terminal thereof movable in the path of the desired waves, the tilt of each conductor being adjusted so that the difference between its length and its projection on the path of a desired wave equals substantially a half wave length of said waves, a translation device connected to the other terminal of said antenna.

18. In combination, a plurality of inverted V-shaped antenna sections each comprising two conductors, means for rotating the vertical plane of at least one of the said sections, means for equally changing the tilt of the conductors to any desired angle, the tilt of each conductor being adjusted so that the difference between its length and its projection on the path of a desired wave equals substantially a half wave length of said wave, a receiver connected to one terminal and a suitable impedance to the other terminal of the said section.

19. An end-on unidirectional antenna array for receiving waves from a distant source comprising an exciter and a reflector lying in the same plane, said exciter and reflector each comprising a plurality of V-shaped antenna sections colinearly arranged and electrically connected, said sections comprising conductors tilted so that the length of each conductor is equal to its projection on the path of the received waves plus one-half wave length of said waves, each reflector section being positioned a quarter wave length farther away from said source than a corresponding exciter section, a receiver connected to the exciter, and a suitable terminating impedance connected to the reflector.

20. A broadside unidirectional antenna array for receiving waves from a distant source comprising an exciter and a reflector, said exciter and reflector each comprising a plurality of parallel V-shaped sections having conductors tilted so that the length of each conductor is equal to its projection on

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the path of the received waves plus one-half wave length of said waves, each exciter section being in the same plane with a reflector section, the exciter sections being positioned an equal distance from said source and each reflector section a quarter wave length further away from said source than its corresponding exciter section, a receiver associated with the exciter, and a suitable terminating impedance associated with the reflector.

21. An antenna comprising a conductor having a length substantially equal to an odd multiple of a quarter wave length of a given wave, said antenna being tilted at an angle such that its projection on the path of said wave is equal to the antenna length minus a half wave length, an impedance connected to one terminal of said antenna, said impedance being equal to the surge impedance of the antenna.

22. An antenna comprising a conductor having a length substantially equal to a multiple of a half wave length of a given wave, said antenna being tilted at an angle such that its projection on the path of said wave is equal to the antenna length minus a half wave length, an impedance connected to one terminal of said antenna, said impedance being equal to the product of the antenna surge impedance and the sine of said angle.

In witness whereof, I hereunto subscribe my name this 5th day of October, 1929.

EDMOND BRUCE.

PLAINTIFF'S EXHIBIT No. 43

RADIO CORPORATION
OF AMERICA
ENGINEERING DEPARTMENT
66 BROAD STREET
NEW YORK

PATENT DEPARTMENT
RECEIVED
File - I
JAN 9 1930
ANSWERED

Mr Taylor
Please docket
for Mr Trimble
W.

January 8, 1930

To: Mr. H. G. Grover - Patent Attorney
From: Mr. C. H. Taylor

Re: Patent Disclosure

Dear Mr. Grover:

I am attaching hereto a Patent Disclosure submitted by Mr. P. S. Carter covering the description of a new type of directional antenna.

You will note that an antenna of this type is now under construction and will be used for the San Francisco circuit as soon as completed and if successful will be left in circuit for pre-commercial test carrying commercial traffic.

Yours very sincerely,

Chas H Taylor

Vice President - Engineering

PLEASE ADDRESS REPLY TO THIS DEPARTMENT FOR THE ATTENTION OF THE WRITER

844

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RADIO CORPORATION
OF AMERICA
INTERDEPARTMENT CORRESPONDENCE

TO: Vice-President - Engineering
FROM: Mr. P. S. Carter

DATE January 7, 1930
FILE No. I

SUBJECT: Patent Disclosure
LOCATION:
REFERRING TO:

Dear Mr. Taylor:

Attached are two copies of a brief description of a new type of directional antenna. This is the antenna which we are building near the Development Building in order to have an antenna directed on San Francisco to be used for experiments. Some of the poles of the old horizontal harmonic antenna are being used for this job..

If this antenna system proves to be as good in practice as it looks theoretically, it will result in the saving of a very large number of costly supporting structures.

Yours very truly
P. S. Carter

PSC/EVH
Cc Mr. H. H. Beverage
Mr. C. W. Hansell

IMPROVED TYPE OF DIRECTIONAL ANTENNA

The antenna system which I shall describe has been in mind several months but was not analyzed in detail until recently. It was written up briefly in my notes of November 29, 1929 and disclosed to Mr. Hansell on the same date.

This system is, without doubt, the simplest and cheapest of any system yet devised, giving the same degree of concentration of radiated energy. After a fairly complete analysis, based upon principles which have all been proved to be sound in actual practice such as with the harmonic antenna, I have plotted the characteristics for both the horizontal and vertical planes in both polar and rectalinear coordinates. These are shown on sheets ~~A, B, C, and D~~ attached. Comparison of these curves with similar curves for the harmonic wire antenna will show that one unit of this improved system gives a concentration which is of the same order as two bays of the horizontal harmonic wire antenna. The horizontal harmonic wire antenna requires the use of 16 masts whereas this system requires only 6. In this improved system, the mechanical and electrical difficulties due to staggering are eliminated as all wire ends are parallel. Also, special devices for elimination of radiation from feeder jumpers, are unnecessary as the system is fed in a similar manner to the standard method of feeding a half wave dipole, the feeder system of which cannot radiate.

DESCRIPTION OF SYSTEM

The fundamental unit of this system consists of two wires (each longer than one half wavelength and preferably of a length equivalent to several wavelengths) fed from a transmission line in a manner such as shown in Fig. 1. It is essential that the angle included by the "V" be of a definite value determined from the length of the "V" according to a certain law which will be given in connection with the discussion of the technical principles involved. When the length of each wire is 8 wavelengths, this angle must be 35 degrees. The power distribution in the plane of the wires (normally the horizontal plane) is as shown in Fig. 2.

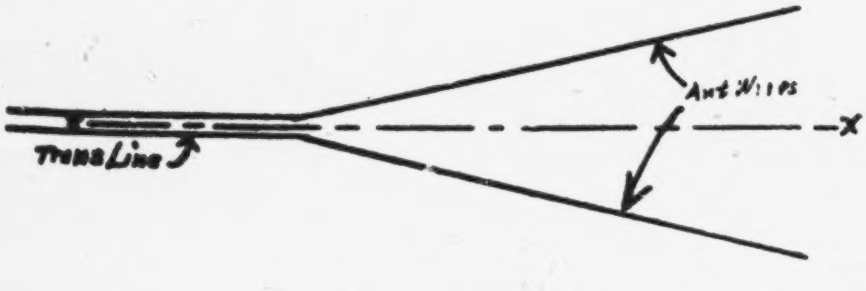


Fig 1.

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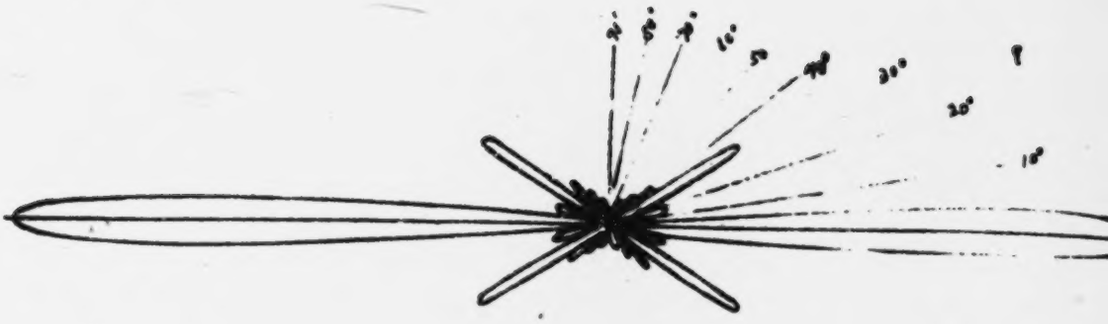


Fig. 2.

In order to prevent radiation vertically upward and downward and thus further increase the concentration in the desired direction, a duplicate system is placed one half wavelength or more above or below the first system and fed in the same phase. This is shown in Fig. 3.

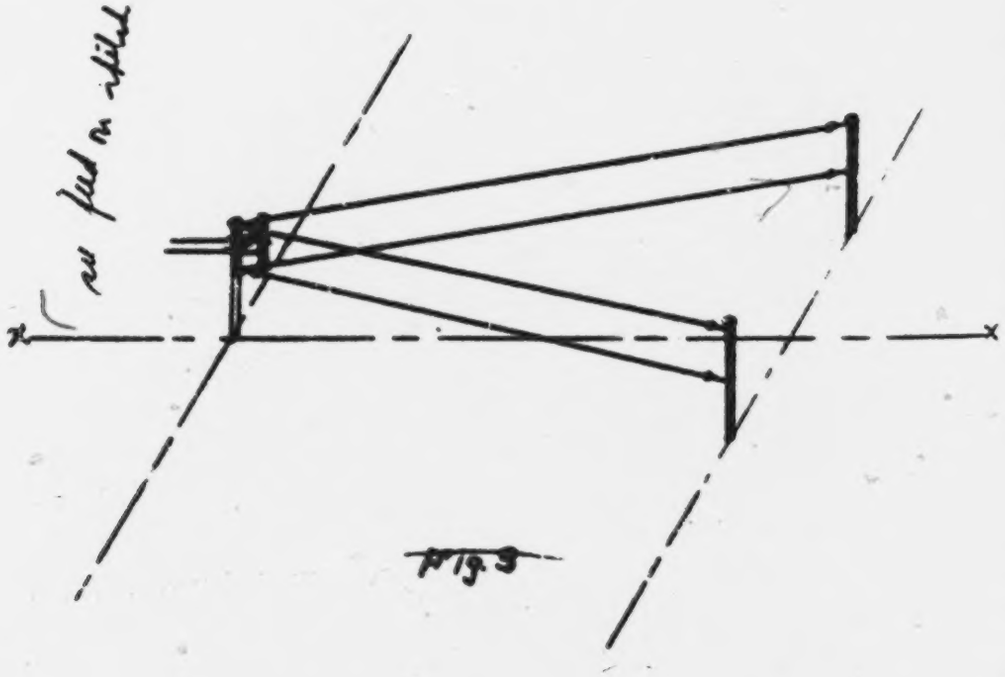


Fig. 3

In the horizontal plane, the power distribution of the system Fig. 3 is the same as shown in Fig. 2. In order to further concentrate the radiated energy and to make the system unidirectional, a duplicate system to that of Fig. 3 is set up at a distance along the line x x equal to an odd number of quarter wavelengths. The second system is fed in either leading or lagging quarter phase depending upon whether it is desired to transmit in one direction or the reverse. The complete single unit is shown in Fig. 4.

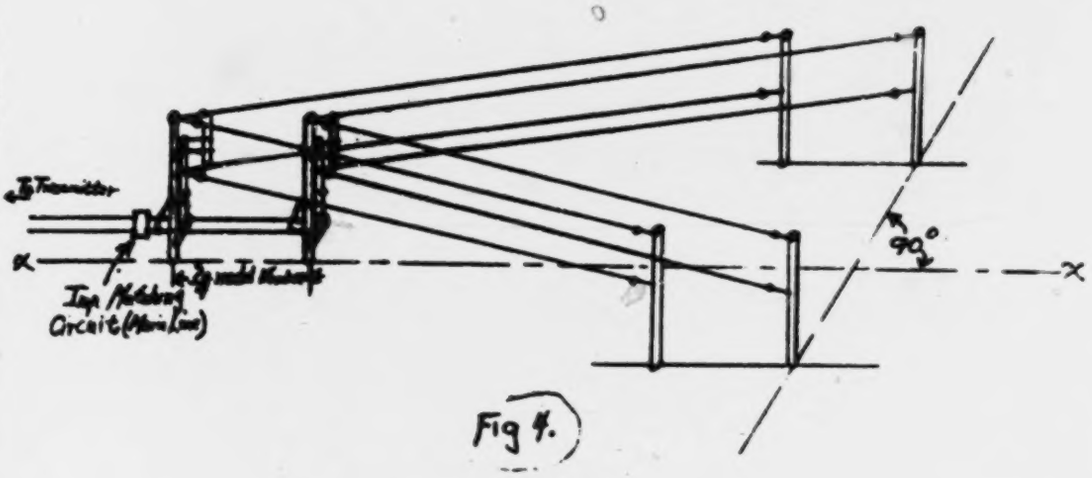


Fig 4.

If greater concentration of radiated energy is desired, several units can be operated in parallel as shown in Fig. 5, in which case, all units are fed in phase, or an array may be made up as in Fig. 6. In the latter case, the phase difference between the different units is made equal to $\frac{\pi S}{\lambda}$ where S is the spacing.

It should be understood that this scheme is not limited to two wires in the vertical plane but may be extended to include any number of wires (preferably an even number) up and down. Fig. 7 shows such a system using 4 wires in the vertical plane spaced $\frac{\lambda}{2}$ apart..

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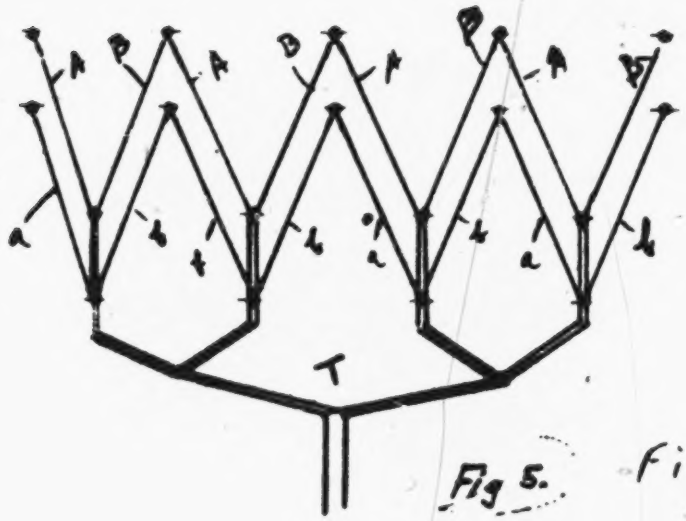


Fig 5.

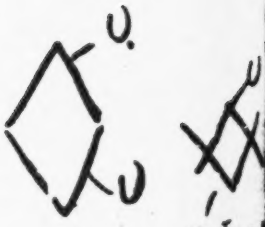


Fig 10

Fig 8



Fig 6.

Fig 9

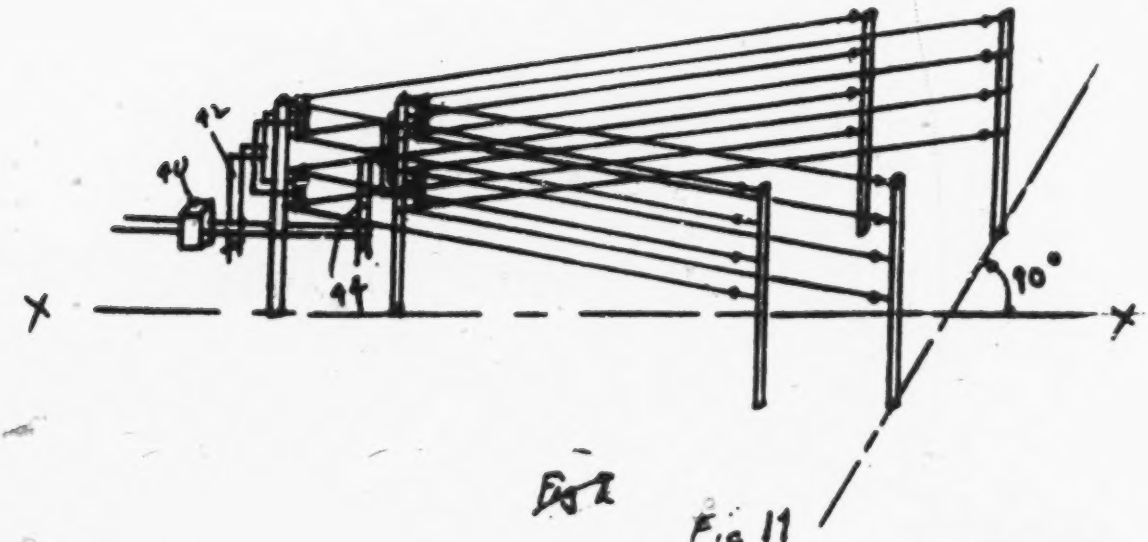


Fig 7

Fig 11

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NCIPLES OF SYSTEM

It can be shown that the field intensity of the radiated e from a straight wire an odd number of wavelengths long is given the formula E or H $\propto \frac{\cos(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ and, from a wire an even number wavelengths long by the formula E or H $\propto \frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$, where is the number of halfwaves long and θ the angle to the wire axis. (The symbol $\propto$ indicates "varies as.")

Let Fig. 8 represent two wires A and B forming a "V" and the line mn bisect the angle between the wires. Call the angle ween A or B and mn α. At any point P on the line mn at a great tance from the wires the radiated waves from symetrical elements A and B have traveled equal distances and therefore will arrive time phase at this point if generated by currents which are in the e phase in A and B. However, the electric field vectors E_A and E_B will be in opposite directions and no radiation will take place ng this line.

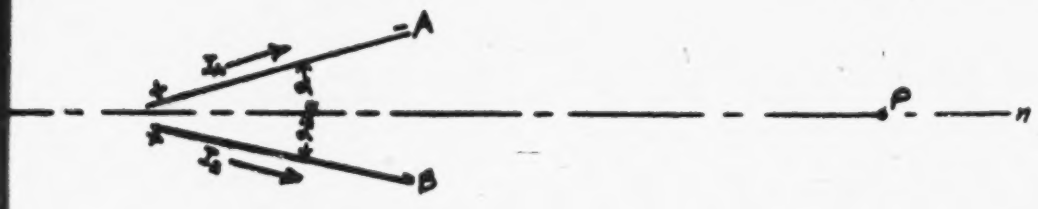


Fig 8.

If currents in phase oppositi.n are flowing in A and B, ch will be the case when fed in the manner shown in either Fig. 9 Fig. 10, the field components will have the same direction at P. , if we make the angle α of the correct value, the maximum radia- n from the pair will take place along the line mn and radiation other directions is to a large extent cancelled. Sheet [redacted] shows correct ues of this angle for various lengths of one side of the "V". When length of each wire is 8 wavelengths and the angle α is 17.5 rees, has already been shown in Fig. 2.

The general distribution is as

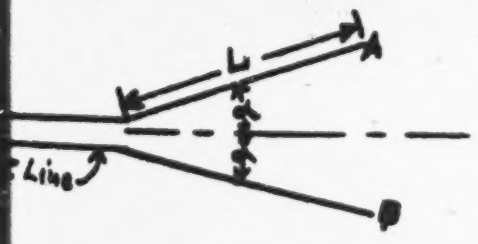


Fig. 9.



Fig. 10

Page Tightly Bound

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850

If Θ is the direction angle to the line mn the phase angle between the time vector component of the field due to A and that due to B is $\pi + 2\pi\frac{d}{\lambda}\cos\Theta$ where d is the spacing between centers of the wires.

However, $d = 2\cdot\frac{1}{4}\sin\alpha$. Hence the phase angle ψ_A becomes $\pi + 2\pi\frac{1}{\lambda}\sin\alpha\cos\Theta$

The total field E for any particular angle Θ, is then equal to the vector sum of $E_A + E_B$ and the magnitude of E becomes (See Fig. 11)

$$|E| = \sqrt{E_A^2 + E_B^2 + 2E_AE_B\cos(\pi + 2\pi\tfrac{1}{\lambda}\sin\alpha\cos\Theta)}$$



Fig. 11

The intensity if energy flow w is equal to $E\times H = E^2$ and $W = E^2 = E_A^2 + E_B^2 + 2\cdot E_A\cdot E_B\cdot\cos(\pi + 2\pi\frac{1}{\lambda}\sin\alpha\cos\Theta)$

Having plotted curves of power distribution for a single wire of length L the field distribution in the plane of the wires can be determined from such curves and the last equation. Fig. 2 was obtained in this manner.

In other planes the directions in space of the components E_A and E_B of the electric field E of the traveling wave are not parallel and in general unequal in magnitude and in different time phase. These facts must be correctly taken into account in determining the resultant field in any direction in space. At any angle in the vertical plane including the line mn the time phase angle is constant and equal to 180 degrees (the currents in the wires being in phase opposition) but the angle between the directions of the field vector components in space varies from 180 degrees in the horizontal direction to 90 degrees in the vertical.

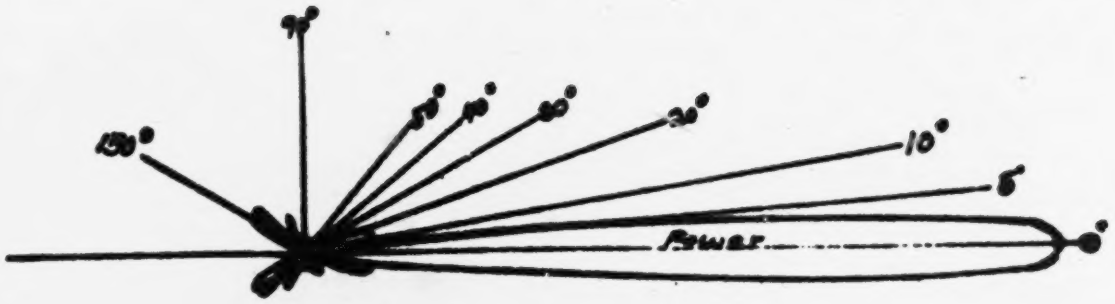
The principles involved in the placing of a duplicate system, or several duplicate systems, all fed in phase and one above the other, to give greater concentration in the vertical plane, are well known and need not be gone into further here. The same applies to the use of two or more systems, one behind the other, fed in successive quarter phase relation, to produce a unidirectional and give further concentration both vertically and horizontally. The principle of using an array of several systems side by side is also well known.

Rocky Point, New York
January 4, 1930

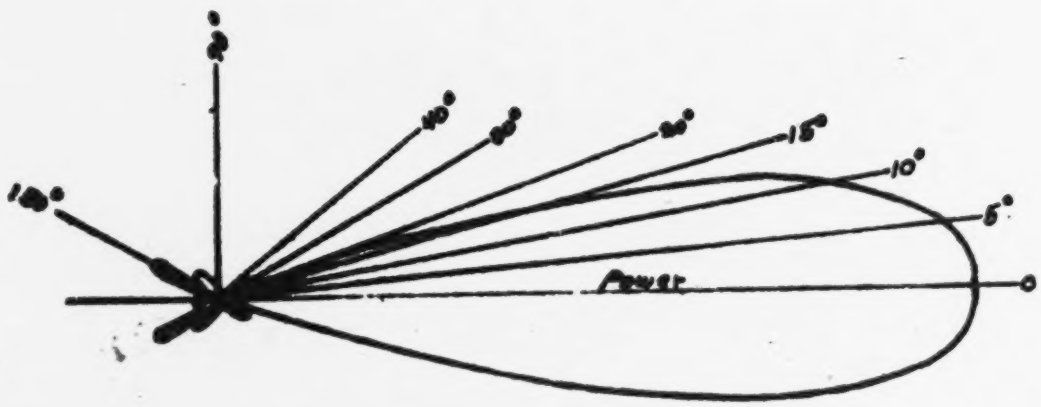
P. S. Carter

P. S. Carter

-7-



Horizontal Plane



Vertical Plane

POWER DISTRIBUTION CURVES
NEW "V" TYPE ANTENNA

Rocky Point, N.Y.
Dec 3 '29
P. S. Carter

Transmitter
1/16/30

43/9

RADIO CORPORATION OF AMERICA
233 BROADWAY, NEW YORK
ENGINEERING DEPARTMENT

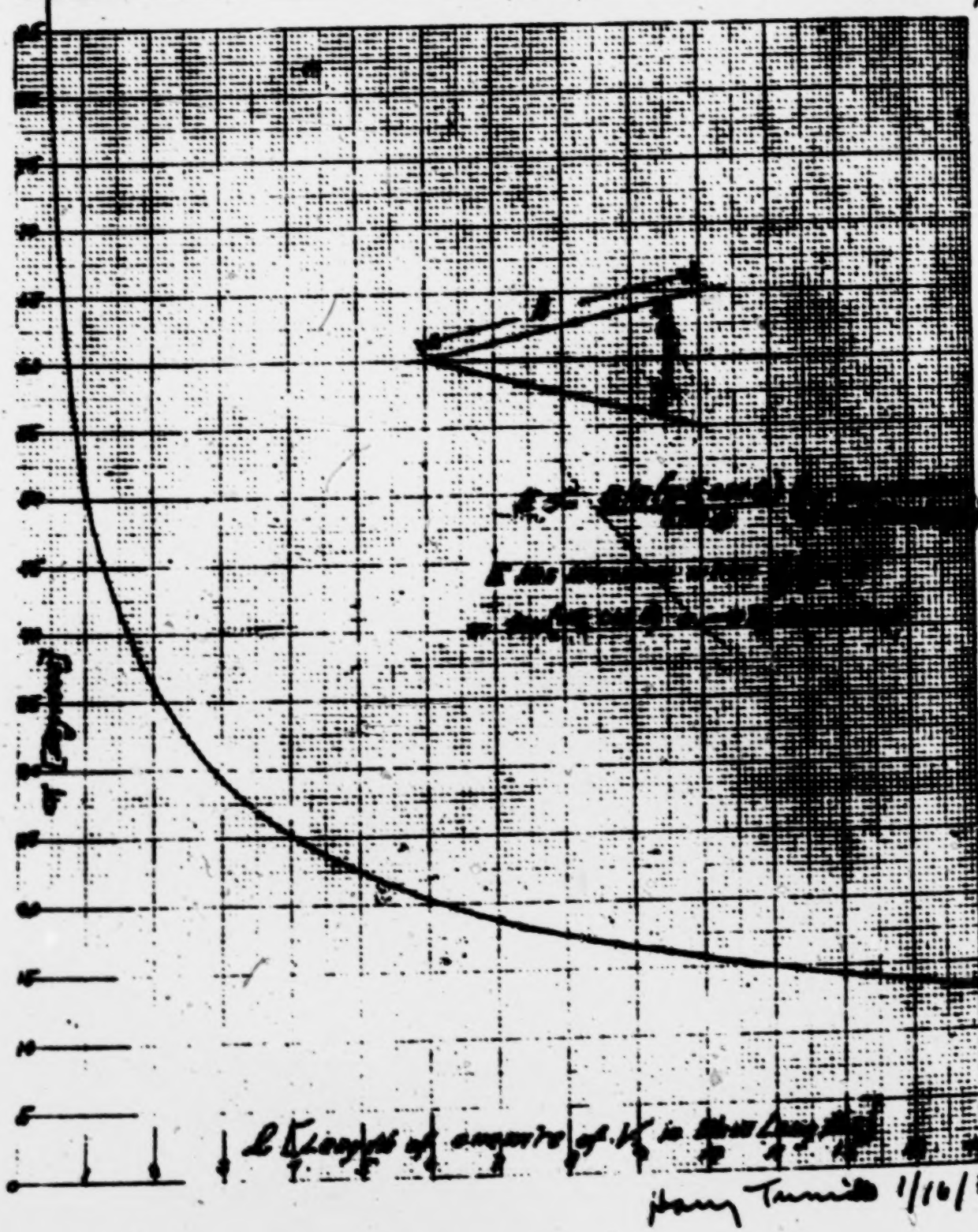
Title Correct Angle between Wires for V Antenna vrs. Length of Wires

Drawn by R.S. Carter Date 1/16/30

No. 8

To Accompany:

Approved by OBC



Harry Turner 1/16/30.

Form 101. 5000. 8-29.

INTERDEPARTMENT CORRESPONDENCE

TO: Patent Department
FROM: Mr. H. Tunick

DATE April 1. 1930.
_____OFFICE
FILE No.

SUBJECT: Docket 4305

Carter promised to send in further information on this case on March 26, 1930 giving me the relation in simple form between the length of wires used and the angle between them in order to obtain maximum radiation on the line of the bisector.

HT:AU

43/4

663
854

R.C.A. COMMUNICATIONS, INC.

PATENT DEPARTMENT
RECEIVED
MAY 10 1930

INTERDEPARTMENT CORRESPONDENCE

TO: Mr. Harry Tunick, Patent Department
FROM: Mr. P. S. Carter

DATE May 9, 1930
ANSWERED

SUBJECT: Docket #4205

Dear Mr. Tunick:

Due to the pressure of other work, mostly in connection with tests and adjustments of the antenna system covered by the above docket, I have been delayed in the writing of a more detailed outline of the principles involved in this system.

Attached you will find a revised description of the principles in which I have given a little more detailed explanation of the law by which the correct angle included by the V is determined. I have also corrected the errors which I found I had made in copying from my original notes. You should now have sufficient information to complete the application papers.

A few days ago I forwarded you a copy of the report of tests on this antenna. The results so far have proved even better than I had anticipated and we expect to build a number of commercial models of this system very soon. For this reason I believe it important that patent papers be filed as soon as possible.

It is believed very important to make applications in foreign countries in this case as it seems impossible to keep news from spreading. Yesterday Mr. Winterbottom and others visited our building and were shown this antenna system. Among the party was a man representing the Holland Company. Several years ago we had a case where a visitor from a foreign country observed certain inventions of Mr. Alexanderson in use and within a short time applied for patents in nearly all the countries of Europe. This resulted in our being unable to use our own system in Poland without paying large royalties to this man.

Yours very truly
P. S. Carter
P. S. Carter

PSC/MVH
Cc Mr. C. W. Hansell

May 10, 1930

#5#

PRINCIPLES OF SYSTEM

The polar diagram of the relative field strength of the radiated wave from a wire several wave lengths long contains as many ears per quadrant as the length of the wire in terms of wave length, For instance, there are four ears per quadrant for a wire four wave lengths long and 4 1/2 ears for a wire 4 1/2 wave lengths long. This is true for any plane including the wire and in a solid diagram these ears become cones. ~~HX~~ Figure A is a polar diagram of relative amplitude for a wire five wave lengths long. The instantaneous direction of the field is reversed for each suceeding ear as indicated by the + and - signs.

The law of variation of field intensity with the direction angle to the wire was deduced by concidering the wire to be equivalent to a very large number of very short doublets and adding up the field components at any point P, having a direction angle θ to the axis of the wire, while correctly taking into account the relative currents along the wire and the phase differences of the elemental field components due to the differences in time taken to travel to the point P. In this treatment the point P is considered as being at a great distance from the wire as compared to the length of the wire so that all lines become essentially parallel.

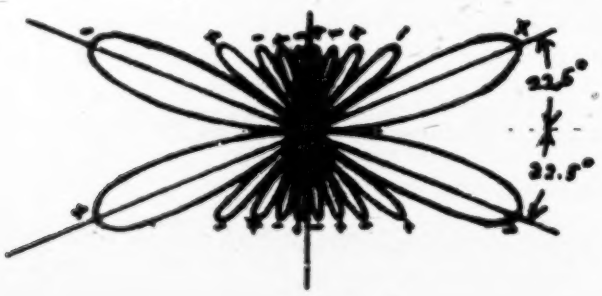


Fig. A.

Such an analysis results in the formulae:

E or $E \propto \frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ for a wire an odd number of half wave lengths long,

and E or $E \propto \frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ for a wire an even number of half wave lengths long,

in which "n" is the number of half wave lengths long, θ, the direction aggle to the wire as axis. The symbol "$\propto$" indicates " is proportional to". 11/11

Let Fig. 8 represent two wires A and B forming a "V" and let the line mn bisect the angle between the wires. Call the angle between A or B and mn α. At any point P on the line mn, at a great distance from the wires, the radiated waves from symmetrical elements of A and B have traveled equal distances and therefore will arrive in time phase at this point if generated by currents in the same phase in A and B. However, the electric field vectors E_A and E_B will be in opposite directions and no radiation will take place along this line.

Fig. 8

If currents in phase opposition are flowing in A and B, which will be the case when fed in the manner shown in either Fig. 9 or Fig. 10, the field components will have the same direction at P. Now, if we make the value of the angle α that which coincides with the direction of maximum radiation from one wire alone, the maximum radiation from the pair will take place along the line mn and radiation in other dirpetions is to a great extent cancelled. When the length of each wire is 8 wave lengths and the angle α is 17.5 degrees the power distribution in the plane of the wires is as has already been shown in Fig. 2.

Fig. 9 Fig. 10

The correct value of the angle α is value of θ for which $\frac{\sin(n\frac{\pi}{2}\cos\alpha)}{\sin\theta}$ is a maximum when the wires are an odd number of half wave lengths long and the value of θ for which $\frac{\sin(n\frac{\pi}{2}\cos\alpha)}{\sin\theta}$ is a maximum when an even number of half wave lengths long. The following two equations give this angle exactly for these two cases:

α = the smallest value obtained from $\tan(n\frac{\pi}{2}\cos\alpha) = n\frac{\pi}{2}\tan\alpha\sin\alpha$

for wires an odd number of half wave lengths long.

α = the smallest value obtained from $\tan(n\frac{\pi}{2}\cos\alpha) = -n\frac{\pi}{2}\tan\alpha\sin\alpha$

for wires an even number of half wave lengths long.

The curve of Sheet 8 gives the values of this angle for lengths up to 14 wave lengths. For practical purposes the empirical formula $\alpha = 90.9(\frac{l}{\lambda})^{-0.513}$ Degrees (where l = length and λ = wave length, both in same units of measure) is sufficiently accurate.

The power distribution in the plane of the wires for the V element can be obtained as follows: If ϕ is the direction angle to the center line of the pair the phase angle between the time vector component of the field due to A and that due to B is $\frac{2\pi d}{\lambda}\cos\phi$ where d is the spacing between centers of the wires.

However, $d = \frac{l}{n}\sin\alpha$. Hence the phase angle ψ becomes $\frac{2\pi l}{n\lambda}\sin\alpha\cos\phi$. The magnitude of the total electric field E for any particular angle ϕ is then equal to the vector sum of

of E_A and E_B and the magnitude of E becomes(See Fig. 11)

$$|E| = \sqrt{E_A^2 + E_B^2 + 2 E_A \cdot E_B \cos\left(\pi + 2\pi \frac{d}{\lambda} \sin\alpha \sin\phi\right)}$$

Fig. 11

The intensity of energy flow (power) w is equal to E x H = E^2 and $w = E^2 = E_A^2 + E_B^2 + 2 \cdot E_A E_B \cos\left(\pi + 2\pi \sin\alpha \sin\phi\right)$

Having determined the curves of field distribution for a single wire of length L substitution of values obtained from these curves in the above equation (with due regard to signs) gives the desired values of intensity of radiation in various directions from the element.

In other planes the directions in space of the components E_A and E_B of the electric field E of the traveling are not the same and, in general, of unequal magnitude and in different time phase. These facts must be correctly taken into account in determining the resultant field in any particular direction in space. At any angle in the vertical plane including the line am the time phase angle is constant and equal to 180 degrees (the currents in the wires being in phase opposition) but the angle between the field vector components in space varies from 180 degrees in the horizontal direction to 2π in the vertical.

The principles involved in the placing of a duplicate system, or several duplicate systems, all fed in phase and one above the other, to give greater concentration in the vertical plane are well known and need not be gone into further here. The same applies to the use of two or more systems fed in successive quarter phase relation, to produce a unidirectional system and give further concentration both horizontally and vertically. The principle of using an array of several systems side by side is also well known.

The are numerous other combinations of the above described elements which I have not shown such as two V combinations placed ~~same~~ so as to form a diamond, two V's crossing at the center of their plots and further combinations of these combinations.

Rocky Point, N. Y.
May 8, 1930.

P. S. Carter

N.J. May 10, 1930

43/15

858
667

Form 236. 50M. 9-29.

INTERDEPARTMENT CORRESPONDENCE

TO: Mr. P. S. Carter
FROM: Mr. Harry Tunick

DATE May 14, 1930.
.....OFFICE

SUBJECT:

FILE No.

I am sending you herewith a rough draft of United States patent application papers covering your invention described in our docket 4805. Please feel free to make thereon any additions, corrections or suggestions which will tend to more fully disclose the invention.

After inspecting the rough draft please return it to me so that I may have the final papers drawn up for you to execute.

Harry Tunick

HT:AU
Encs.

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668

DOCKET 4866

Return To

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, PHILIP STAATS CARTER, a citizen of the United States, and a resident of Port Jefferson, Long Island, New York, have invented certain new and useful improvements in

ANTENNAE

of which the following is a specification:

This invention relates to antennae and especially to directional antennae or antennae systems.

If a wire relatively long, relative to the working wave length; namely, a plurality of half wave lengths long, is excited in a fashion such that standing waves are produced thereon, principally directive radiation will occur in the form of symmetrical cones having their apices at the center of the wire. In cross section, the radiation characteristic would appear as symmetrical hollow cones about the wire. An object of the present invention is to utilize this phenomenon for the directive radiation of electromagnetic energy. To do so, a pair of wires or linear conductors relatively long relative to the working wave length are disposed at an angle such that principal radiation takes place along the bisector of the angle. This angle, in general corresponds to the angle of the principal cone of radiation about one of the conductors.

Still a further object of the present invention is to disclose the proper angle for wires or conductors or radiators either an even number of half wave

lengths long or an odd number of half wave lengths long, and in general to dispose the angle for best directional propagation for wires of any finite length.

A pair of conductors disposed in the manner described will radiate equally well in two directions, namely, towards the diverging end of the wires and ~~away from~~ towards the converging end of the wires. That is to say, the antenna system so far described is bidirectional. A further object of the present invention is to provide an arrangement ~~whereby the system becomes~~ unidirectional. This is accomplished by placing a similar parallel pair of wires an odd number of quarter wave lengths away from the wires forming the antenna proper in the direction taken along the bisector or the angle formed by the wires. The second pair of wires may be left unenergized or floating, or they may be energized in proper phase such that for one direction radiation cancelation occurs, whereas in the other direction there is strengthening of the propagation of electromagnetic waves. ~~Ordinarily, the antenna as has described will have the pairs of wires in a horizontal plane whereby the beam of energy radiated occupies a small horizontal angle.~~ To concentrate the beam in a transverse ~~direction, namely, vertically~~ plane, ~~that is, perpendicular to the plane of the pairs of wires, usually in vertical planes~~ is a further object of the present invention, and this is accomplished by placing similar pairs of wires in planes parallel to the planes of the first mentioned pairs of wires ~~the planes being spaced apart a number of half wave lengths~~ preferably at least a half wave length.

To additionally concentrate the beam of energy radiated, systems of the nature outlined hereinbefore may be placed in broadside whereby there

is added concentration of the radiated beam of energy in a horizontal plane, and, by placing more systems or stories of systems above one another, there will be added concentration of the beam in a vertical direction. The invention is further described in connection with the accompanying drawing, in which

Figure 1a illustrates generally the principal omnal radiational characteristic of a long conductor upon which standing waves are produced,

Figure 1b illustrates in cross section, the radiation characteristic of a wire five wave lengths long,

Figures 2a, 2b and 2c indicate various forms of the fundamental unit of the present invention wherein long linear conductors having standing waves thereon are disposed at an angle such that principal radiation occurs along the direction of the bisector of the angle,

Figure 3 indicates the bidirectional characteristic of one of the units shown in figure 2.

Figure 4 illustrates an antenna system for concentrating the directional beam radiated from one of the units shown in figure 2,

Figure 5 illustrates the arrangement of a plurality of units such as shown in figure 2 for obtaining unidirectional propagation [redacted] plane,

Figures 6 and 7 illustrate respectively the power distribution in the horizontal and vertical planes from an antenna system such as shown in figure 5,

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671

Figure 8 illustrates a broadside arrangement of unidirectional units for further concentrating the beam in a horizontal plane;

Figure 9 indicates in plan view an end-on arrangement of units for concentrating the beam in a horizontal plane,

Figures 10 and 10a indicate diamond shaped arrangements of conductor paths for obtaining unidirectional propagation,

Figure 11 illustrates a preferred form of the invention for concentrating a unidirectional beam of energy horizontally and vertically, and

Figure 12 is a graph showing the proper relationship between the length of a single conductor of a pair of conductors and the angle to be given it relative to a desired direction of propagation according to the present invention,

In general, as shown in figure 1a, about a wire 2 long relative to the working wave length, there are two principle hollow cones 4, 6 of radiation. The cones are symmetrical about the wire 2 and the axis of the cones coincides with that of the radiator 2. For a given wire, at a given wave length, the angle α between the axes Y-Y, of each lobe or ear of the cone which appears as such in cross section, and the wire 2 remains substantially constant.

More specifically, a cross section of the solid polar diagram of a wire a number of wave lengths long having standing waves thereon, contains as many ears per quadrant as there are wave lengths in the wire. Thus, as shown in figure 1b, for a wire five wave lengths

long, there are five ears in each quadrant, the principal lobes of radiation occurring along the axes Y-Y. As indicated, the instantaneous direction of the field represented by each ear is reversed.

Now, if it is desired to radiate energy principally in the direction of axis X-X of figure 2, the conductors shown in figure 1, should be turned an angle α relative to the direction X-X; and, in order to increase still further the directional characteristic along the axis X-X, according to the present invention, two wires should be used which make an angle α with the axis X-X on opposite sides of the axis in such a fashion that the axis and the pair of wires lie in a single plane. In other directions than along the axis X-X, radiation cancelation will occur mainly, as a result of which, a pair of wires disposed at the angle α with respect to the X-X axis will have a radiation characteristic such as shown in figure 3.

By considering a long wire the equivalent of a very large number of ~~short~~ ~~half-wave~~ elementary (Hertz) oscillators, by adding up the field components at any point P having a direction angle θ relative to the axis of the wire where the point P is ~~considered as being~~ a great distance from the wire as compared to the length of the wire such that all lines from point P to any point on the wire are essentially parallel, it can be shown that the field strength H is given by the following proportionality for a conductor an odd number of half wave lengths long:

$$H \propto \frac{\cos\left(\pi \frac{n}{2} \cos\theta\right)}{\sin\theta}$$

43/21

The legend "n" indicates the number of half wave lengths contained in the wire.

For a wire an even number of half wave lengths long, in similar fashion, above the field strength H, is given by the following proportionality:

$$H \propto \sin\left(n\frac{\pi}{2}\cos\theta\right) / \sin\theta$$

Where n as above indicates the number of half wave lengths on the wire.

The value for which the angle θ in either of the above equations makes the expression a maximum value gives, of course, the value for the angle α with the wire should be disposed at relative to the direction of desired wave propagation. The manner of obtaining the critical value of θ for either of the above equations may obviously, be readily determined, the value for wires up to fourteen wave lengths long is given graphically in figure 18. For practical purposes the empirical formula

$$\alpha = 50.9\left(\frac{l}{\lambda}\right)^{-0.513} \text{ degrees}$$

where l equals the length of the wire and λ the wave length, both in the same units of measurement, is sufficiently accurate. Where a pair of wires are used in accordance with the present invention, they should be spaced apart at an angle equal to twice the angle α as determined above.

-6-

9/22

In order to obtain a bidirectional unit having a characteristic
as shown in figure 3, as already indicated, any of the arrangements
in figure 2 may be utilized. The fundamental unit is shown in
re 2c where a transmission line 10 supplies high frequency energy
pair of wires A,B forming the angle 2 α with each other, the
the angle made by one of the conductors
le α with the axis XpX along which it is desired that the radiators
propagate energy. The conductors A,B, are joined together at their
which [illegible] the axis XpX as shown, and are fed intermediate
the ends in a fashion similar to that in which a half wave length
illator is fed intermediate its ends, [illegible]
desired, of course, as shown in figure 2b the transmission line 10
terminate the extremities of linear radiators A,B, and
connect them together.

The arrangement shown in figure 2c is, however, preferred, for
allows of tuning of the antenna unit comprising the pair of wires A,B.
transmission line 10 feeds energy to a U-shaped loop 12 [illegible],
the legs of which are short circuited by an adjustable
rt circuiting strap 14 [illegible] representing a voltage nodal
nt. The ends 16 of the loop 12 [illegible] supply energy in phase opposition to the conductors A,B. Adjustment
impedance such that there is no reflection along transmission line 10
accomplished along the legs of the loop by suitable adjustable tapping
[illegible] It may be mentioned here that energy to the radiators A,B
should always be fed thereto out of phase for otherwise at a distant
nt P along the axis XpX there would be radiation cancelation, and it is

43/23

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Moreover, it should be clearly understood that the wires of each unit can be of any length whatsoever provided they are placed at the correct angle for their length. For best tuning, the total over-all length of both of the wires and the "U" loop terminating them should be effectively an integral number of half wave lengths, but, the portion forming the radiation element can be of any length, [redacted]. The law governing the correct angle for lengths between odd and even number of half wave lengths, is not given due to its complexity, but the empirical formula and the curve of figure 18 will be found [redacted] accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths. 43/24

INSERT 8 - DOCKET 4305

The vertical spacing of the units one above the other need not be made an integral number of half wave lengths. ~~The spacing of a half wave length prevents vertical radiation.~~ In addition it should be noted that for wires several wave lengths long, vertical radiation is either zero or practically very small. Specifically, it is zero for wires whose lengths are equal to an even number of half wave lengths, and small for wires an odd number of half wave lengths long. For wires whose length approaches the order of magnitude from 6 to 10 wave lengths, a spacing greater than one half wave length is preferred. In practice, where the height of the antenna is limited by economical considerations and wherein it is desired to make ground absorption as low as possible, a good compromise is a half wave length spacing. For transmission of energy having a wave length of 17 or 18 meters, a good practical antenna may be had wherein the lower wires are about three-quarters of a wave length above ground, and the spacing between wires is one-half wave length. Eighty feet poles or masts may be used to support the wires ~~antenna of this character.~~

43/25

to be understood that the unit so far described is not only useful for radiation purposes but may be utilized equally as well for reception. That is, the antenna system according to the present invention is equally well suited for any type of radiant action whether it be collection of radiation energy or the transmission thereof.

In order to prevent undesired high angle radiation, and in order to concentrate the desired beam in elevation, the scheme shown in figure 4 may be utilized. Here, pairs of wires A,B and A',B' are placed in parallel horizontal planes and supported by masts 20 and suitably insulated therefrom by suitable insulators 22. Both pairs of wires are fed cophasally from a transmission line 24 through conductors 26, the wires of each pair being fed in opposite phase. In order to increase the concentration of radiated energy, the pair A,B and the pair of wires A' and B' are placed apart in horizontal planes preferably one-half wave length apart. Bidirectional propagation ensues along the axis X-X but in a much more concentrated form. In order to obtain a unidirectional radiation characteristic, pairs of units such as shown in figure 3 may be spaced parallel and apart a distance along the axis X-X the bisector of the angle formed by each pair of wires in each unit a distance equal to an odd number of quarter wave lengths. Such a system combined with means for concentrating the beam in a direction traversing the plane of the wires of each unit is shown in figure 5. That is, figure 5 illustrates a

system such as shown in figure 4 duplicated in a direction along the XX axis whereby in a horizontal plane, a directional characteristic is obtained such as that shown in figure 6 and, in a vertical plane a power distribution characteristic as shown in figure 7.

The unit comprising the pair of wires A,B is paralleled by similar pairs a, b spaced apart along the direction XX an odd number of quarter wave lengths and, as shown, three-quarters of a wave length behind the apex 28 of wires A, B by exciting the wires a,b, that the standing current waves thereon are 90 degrees ahead in phase of the standing current waves on wires A,B, whereby energy will be propagated principally along the axis XX towards the diverging ends of the radiators. In order to concentrate the beam of energy so radiated, similar pairs of radiators are placed below the pairs A,B and a, b in planes suitably spaced from the first mentioned pairs of radiators to obtain the desired unidirectional concentration, in a vertical direction. The lower pairs of radiators are excited cophasally with the upper pairs by conductors 36, 36' fed by transmission line 24. In order to tune the various units U-shaped loops 30, 30' are provided, short circuited by straps 38, 38'.

Of course, by exciting wires a,b 90 degrees lagging relative to radiators A,B, unidirectional propagation may be obtained in a vertical direction, or towards the converging ends of the units.

If greater concentration of the radiated energy is desired several systems such as shown in figure 5, for example, comprising an

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effective radiating unit AD and an effective reflecting unit ab may be placed in broadside and excited cophasally. Thus, in figure 8 each of the radiating units A, B shown in plan is provided with a reflecting unit a, b. Through branched transmission lines as shown diagrammatically at T each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves on the units.

The units may be arranged in end-on fashion or coaxially as shown in figure 9 wherein each of the units U is spaced apart in the direction of desired propagation. By making the phase difference between each of the units equal to $2\pi\frac{S}{\lambda}$ where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the standing waves on the succeeding units lag or lead each other by the phase differences given according to the foregoing expression.

Other combinations will readily suggest themselves to those skilled in the art, for example, the units U may be placed diamond shaped fashion such as shown in figure 10, or, they may be superimposed as shown in figure 10a, the wires of each unit traversing each other.

In order to obtain greater concentration of the radiated beam of energy in a direction traversing the plane of each unit, the systems may be extended in the fashion shown in figure 11.

INSERT 3 - DOCKET 4805

The spacing of the antenna and reflector of the system shown in figure 11 where the wires are 6 to 12 wave lengths long is made preferably nine-quarters of a wave length. For wires longer than ten wave lengths, the preferred form should have a greater spacing between the antenna and reflector such as two and three-quarters or three and one-quarter wave lengths. For wires on the order of three or four wave lengths long, the reflector spacing from the antenna should be one and one-quarter wave lengths or less. In general, for maximum concentration, as the length of wires in terms of wave lengths increase, the reflector and antenna spacing should be increased.

INSERT 4

Use of the loop allows of completion of the tuning of the antenna wires by making the total effective tuning length of each wire of the "V" or radiating unit equal to an odd number of quarter wave lengths. The effective radiating length is the length of wire included in the "V" only, since the loop is non-radiating and can be made of any length.

When tuning of the "V" is properly accomplished by the U-loop, the systems presents a pure resistive load to the transmission line. By tapping the line to the legs of the U at a suitable distance from the short circuiting strip, the effective

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resistance of the antenna system can be made equal to the surge impedance of the line, which is a necessary condition for maximum transmission efficiency. 43/30

Here, the system of figure 5 has been duplicated in a vertical direction, giving increased concentration of the beam in elevation. Energy is fed to the system through an impedance matching device 40 and thence cophasally to the reflecting units through a suitable connection 42. Energy is similarly fed to the radiating units through a suitable connection 44. By suitable tuning and by suitable spacing of the radiating pairs of wires and reflecting pairs of wires, unidirectional propagation may be obtained in either direction along the bisector of the angle formed by the wires of each pair.

In each of the systems, of course, for reception, the transmission line would simply be coupled to a suitable receiver, the antenna being directed upon a transmitting station. The wires, though preferably placed in horizontal planes, may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires tilted away from the wall towards the direction in which the beam of energy is propagated.

Having thus described my invention, what I claim is:

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DOCKET 4205

1. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors.

2. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended, and, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

3. A directional antenna comprising a pair of angularly disposed linear conductors disposed in a horizontal plane, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors.

4. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended and disposed in a horizontal plane, and, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

5. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors parallel and similar to said first mentioned pair of conductors and spaced therefrom an odd number of quarter wave lengths measured in a direction along the bisector of the angle of the conductors.

6. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended; means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators; and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction measured along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

43/33

7. A directional antenna comprising a pair of angularly disposed linear conductors disposed in a horizontal plane, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction measured along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

8. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended and disposed in a horizontal plane, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction measured along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

9. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair ~~an odd number of half wave lengths the spacing being taken in a direction perpendicular to the planes of the pairs of conductors~~ in a direction transverse the planes of said pair.

10. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors; and another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair ~~an~~ number of half wave lengths ~~the spacing being taken~~ in a direction perpendicular to the planes of the pairs of conductors.

43/35

11. An antenna comprising parallel pairs of angularly disposed conductors spaced apart along the direction of the bisector of the angle formed by the conductors an odd number of quarter wave lengths, and, similar pairs of conductors in planes parallel to the planes of the first mentioned pairs of conductors, [redacted]

12. A transmitting antenna system comprising parallel pairs of angularly disposed conductors arranged in a horizontal plane having their apices spaced apart an odd number of quarter wave lengths, and similar pairs of conductors disposed in a parallel horizontal plane a distance away from said first mentioned plane [redacted] half wave lengths.

13. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed at an angle equal to twice the angle for which the expression $\frac{\cos(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum.

14. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed at an angle substantially equal to twice the angle for which the expression $\frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum.

15. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed at an angle equal to twice the angle for which the expression $\frac{\cos(\pi \frac{l}{\lambda} \cos\theta)}{\sin\theta}$ is a maximum, and a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

16. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed at an angle substantially equal to twice the angle for which the expression $\frac{\sin(\pi \frac{l}{\lambda} \cos\theta)}{\sin\theta}$ is a maximum, and a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

17. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed at an angle equal to twice the angle for which the expression $\frac{\cos(\pi \frac{l}{\lambda} \cos\theta)}{\sin\theta}$ is a maximum, and a similar parallel pair of conductors ~~equidistant~~ away from the first mentioned pair ~~mounted~~ in a direction perpendicular to the planes of the pairs, ~~of equal number of half wave lengths.~~ 43/37

18. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed at an angle substantially equal to twice the angle for which the expression $\frac{\sin\left(n\frac{I}{\lambda}\cos\theta\right)}{\sin\theta}$ is a maximum, and a similar pair of conductors a distance away from the first mentioned pair measured in a direction perpendicular to the plane of the pairs, ~~of an odd number of half wave lengths.~~

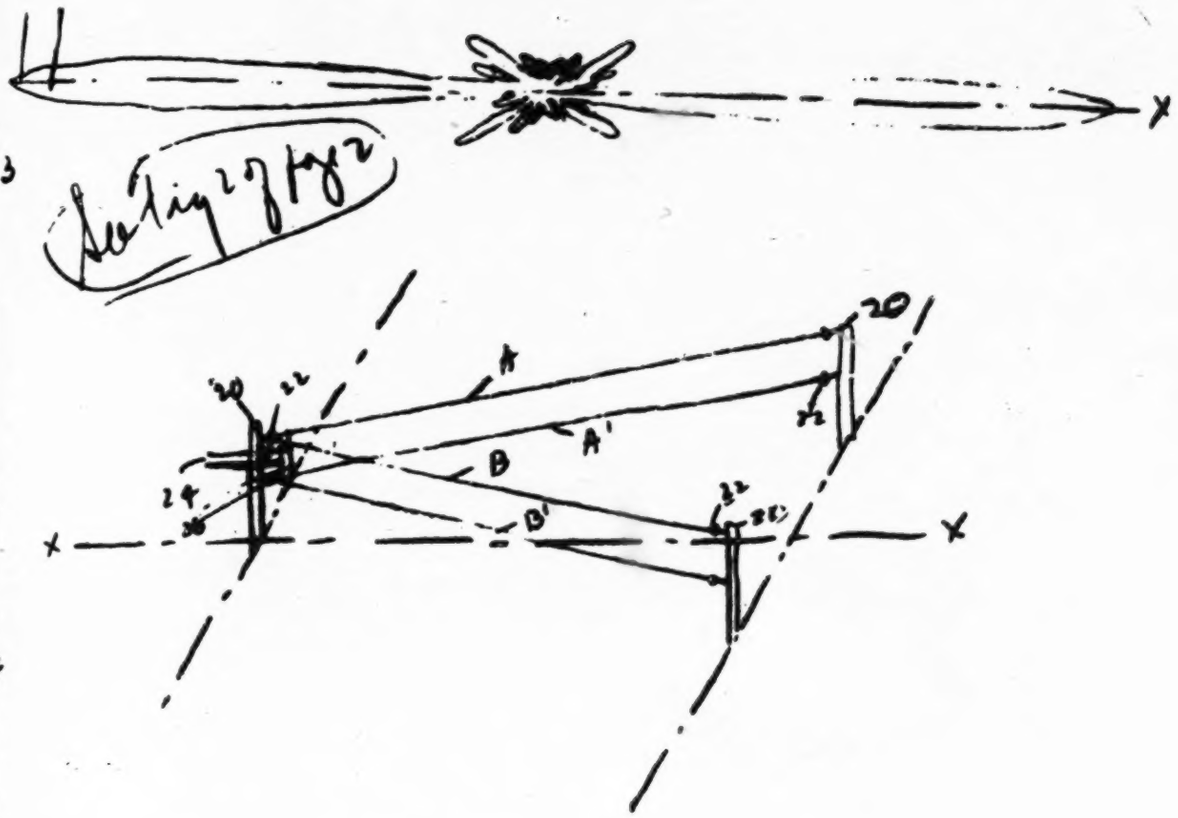
19. An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)^{-0.513}$ degrees.

20. An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)^{-0.513}$ degrees; and, a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair measured along the bisector of the angle of the conductors.

21. An antenna comprising pairs of long conductors, the conductors of each pair disposed at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)^{-0.513}$ degrees, and the pairs being placed in planes substantially an odd number of half wave lengths apart.

22. An antenna comprising pairs of relatively long conductors each pair disposed at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)^{-0.513}$ degrees the apices of each pair being separated by an odd number of quarter wave lengths; and, similar pairs of conductors in a substantially parallel plane, ~~substantially and odd number of half wave lengths apart away from the plane of the first pair of conductors.~~

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Carter
4205

4/1/39

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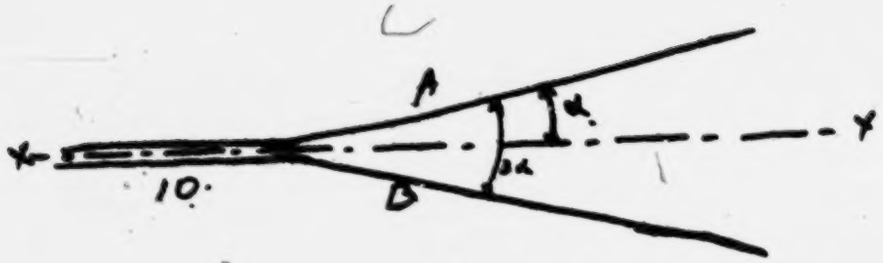


Fig 2b

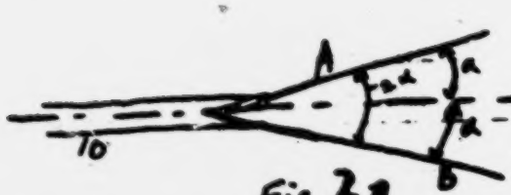


Fig 2a

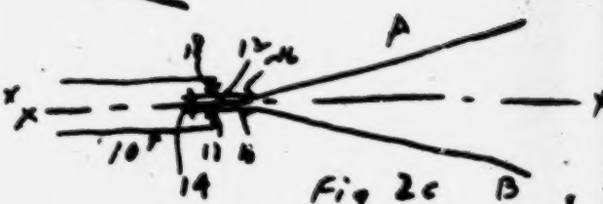


Fig 2c

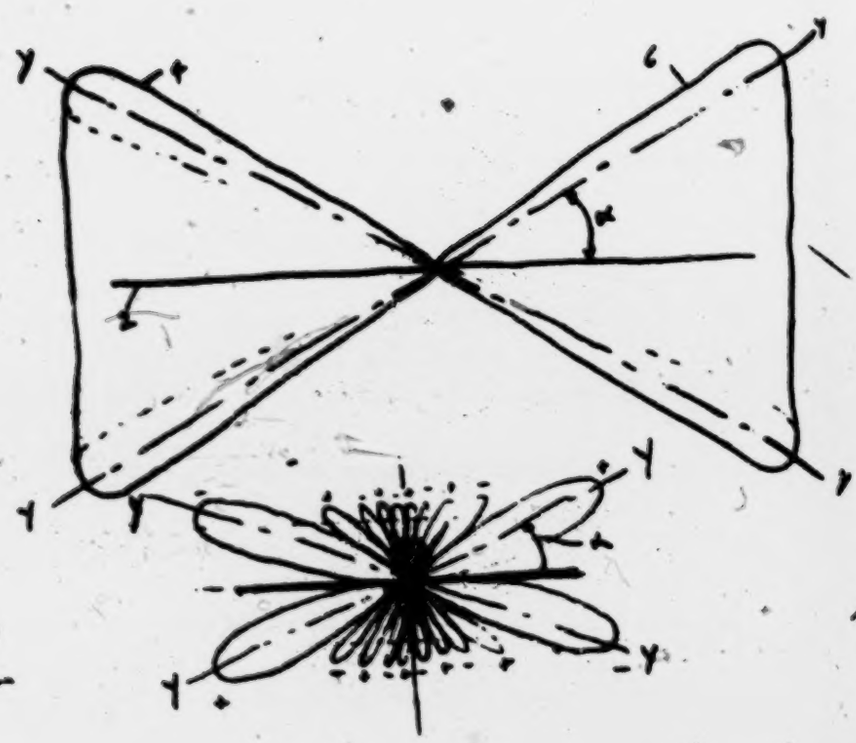


Fig 1a

Fig 1b

P.S. Carter
4205

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883

R. C. A. COMMUNICATIONS, INC.

INTERDEPARTMENT CORRESPONDENCE

PATENT DEPARTMENT RECEIVED MAY 21 1930

Rocky Point, New York

TO: Mr. Harry Tunick, Patent Department
FROM: Mr. P. S. Carter

DATE May 20, 1930
FILE No. I

SUBJECT: Docket #4205

Dear Mr. Tunick:

I am returning the rough draft of the patent application covering Docket #4205 after having made a number of notations in red pencil. These red pencil notations principally cover statements which appear to me to be either misleading or incorrect.

It appears to me that there are some statements in the specification which need a little clarifying. On page one one might gain the impression that it is essential for the proper working of this system that the length of the wires must be an integral number of half wavelengths. These wires can be any length whatever provided the angle is made correct to correspond. For the best tuning the total overall length of both the wires and the "U" loop should be effectively an integral number of half wavelengths but the portion forming the radiation element can be of any length whatever. The law for determining the angle for lengths lying in between odd and even numbers of half waves was not given due to its complexity but the curves and the imperical formula gives the correct values.

On page two a statement was made that the spacing of units one above the other should be an integral number of half wavelengths. Such spacing is not essential. The spacing of a half wavelength would prevent radiation vertically upward but for wires several wavelengths long vertical radiation is either zero or very small to start with. (Zero for lengths equal to an even number of half waves and small for an odd number of half waves). For lengths in the order of 6 to 10 wavelengths a spacing greater than one half wavelength would be better. However, in practice, where height is limited by economy and we wish to make the absorption due to ground as low as possible, the half wavelength spacing is the best compromise. This results in the lower wire being about 3/4 of a wavelength above ground and the spacing between wires 1/2 wavelength when 80 foot poles are used for an antenna for transmission at 17 to 18 meters. In this case the main field is quite weak at the ground and ground losses are reduced to a low value.

On page four the statement is made that Figure 11 illustrates the preferred form of the invention. This is true for wires on the order of 6 to 12 wavelengths long. For wires longer than 10 wavelengths, the preferred form would have a greater spacing between the antenna and reflector, such as 2-3/4 or 3-1/4 wavelengths. For wires on the order of three or four wavelengths long the reflector spacing would be 1-1/4 or less. In general, the longer the wires in terms of wavelength the greater should be the reflector spacing if maximum concentration is to result.

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On page seven the statement is made that the transmission line feeds energy to a "U" shaped loop one half wavelength long. This adjustable loop is usually not one half wavelength long. The object of the loop is to complete the tuning of the antenna wires by making the total effective tuning length of each wire of the "V" equal to an odd number times a quarter wavelength. The effective radiating length is the length of the wire of the "V" only, as the "U" loop is non-radiating, and can be any length. When the tuning is properly completed by the "U" the system presents a pure resistance load to a transmission line tapped on it and by tapping the loop at the correct distance from the short circuiting strip this effective resistance can be made to equal the surge impedance of the line, the necessary condition for maximum efficiency of transmission.

I believe that it would be advisable to incorporate part of the explanations just made in the application so that there can be no doubt as to what the invention covers.

Yours very truly

P. S. Carter

PSC/MVH

P.S. Thanks for copy of Patent 1,623,996 which just came. PSC

11/42

. P. S. Carter
. Harry Tunick

May 24, 1930.

I am sending you herewith the United States patent application papers covering your invention originally described in our docket 4205, which you will kindly execute in the customary fashion.

A check for $1.00 covering the nominal consideration mentioned in the assignment is also attached hereto.

HT:AU
ENCS.

43/4

Page Tightly Bound

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886

Form 236 Com. 1934 6-30

R. C. A. COMMUNICATIONS, INC.

INTERDEPARTMENT CORRESPONDENCE

TO: Mr. Harry Tunick, Patent Department
FROM: Mr. P. S. Carter

DATE June 5, 1930
FILE No. I

SUBJECT: Docket #4205

PATENT DEPARTMENT
RECEIVED
JUN 1930

Dear Mr. Tunick:

Attached you will find the patent papers covering the above docket, which I have executed as requested in your letter.

I note that no claims have been made for combinations of these units in broadside although this was described in more or less detail in the specification. Possibly the addition of claims covering these combinations is not necessary but it would seem that this would be as important as the claims covering combinations for concentration in the vertical plane and for producing uni-directional radiation. Upon inspection of the specification and the drawings I fail to find any errors.

Yours very truly

P. S. Carter

P. S. Carter

PSC/MVH

6/9/30

UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF NEW YORK

- - - - - - - - - - - - - - - - - - - -

RADIO CORPORATION OF AMERICA, :

Plaintiff, :

v. : Equity No. 7234

MACKAY RADIO & TELEGRAPH COMPANY, INC., :

Defendant. :

- - - - - - - - - - - - - - - - - - - -

STIPULATION

IT IS HEREBY STIPULATED between the solicitors for the respective parties hereto that the following insertions, deletions, and changes appear in Red Pencil on the draft of Philip Staats Carter's Specification and Claims received in evidence as part of Plaintiff's Exhibit 43 (immediately following Mr. Tunick's memo to Mr. Carter of May 14, 1930):

Page 2, line 7 from bottom, after the word "transverse", the word -- plane-- is inserted; line 6 from bottom, the words "direction" and "vertically" are deleted, and after the inserted word "usually", the phrase --the vertical plane-- is added; line 3 from bottom the words "number of" are deleted and after the inserted word "preferably," the phrase --at least a-- is inserted; the "s" on the word "lengths" is deleted.

Page 3, line 4, the word --plane-- is substituted for "direction"; line 8 from bottom, "a vertical" is deleted and --the horizontal-- substituted; the phrase

v3/45

--of the vertical plane-- is inserted after the word "direction"; both insertions on line 8 are deleted in black pencil.

Page 4, fourth paragraph, line 2, after the word "vertically," the phrase --when the length of wires is of the order of 6 to 12 wavelengths.-- is inserted.

Page 5, line 16, "half wave" is deleted and --very short, (Hertz)-- substituted therefor.

Page 7, line 10 from bottom, the word "one-half" is deleted; line 9 from bottom, "wave length long" is deleted; line 7 from bottom, the phrase "are always at maximum potentials" is deleted; line 6 from bottom, "and" is deleted.

Page 8, line 6, "vertical" is deleted and --high angle-- substituted; line 13, the words "a vertical" are deleted and --the horizontal-- inserted, and after the word "direction", the phrase --of the vertical plane,-- is inserted; both insertions are deleted in black pencil; line 15, the phrase "number of half wave lengths" is deleted and --by any convenient spacing-- substituted; the words --at least-- are inserted after the word "preferably", line 16, after the word "apart", the following sentence is inserted: --The lower pair should be at least one-half wave length above ground.--

m/m

Page 9, line 7, the word "five" is deleted and

--nine-- substituted therefor.

Dated, New York, N.Y.,
April 21st, 1936.

Sheffield Bell
Solicitors for Plaintiff

Darby & Darby
Solicitors for Defendant,

F3/77

PLAINTIFF'S EXHIBIT No. 44

Mr. Jumick
Patent Dept.

TRANSMISSION TESTS

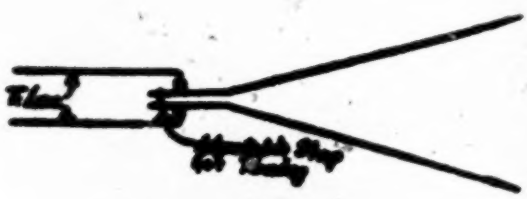
MODEL "D" PROJECTOR

DESCRIPTION OF PROJECTOR.

The fundamental element of this system is a wire, having a length equivalent to several wave lengths, bent at the center so as to form a V and fed from a transmission line in a manner similar to that in common use in feeding a half wave dipole. The sketch below shows this scheme. If the angle included between the sides of the "V" is made of the correct value (this value depending upon the dimensions of the V according to rather complex law) an excellent bidirectional radiating unit is obtained, the maximum radiation taking place along the line bisecting the angle. If the length of each side of the V is made four wavelengths the correct value for the included angle is 50.4°.



Fundamental Element



Modification to Permit Adjustments

If eight wavelengths, the correct value is 35°. In the system tested the length was seven and three quarter wavelengths.

The complete single bay of this antenna consists of two pairs of V wires. The two units of one pair are spaced apart a half wave length or more, one being above the other, and are fed in the same phase. The two pairs are spaced apart an odd number of quarter wave lengths along the center line and fed in the correct phase relation to produce a unidirectional system in whichever of the two directions it is desired to radiate. In the system tested (at a wavelength of 17.3M) the vertical spacing was one half wavelength and the spacing between pairs two and one-quarter wavelength. The system is suspended from six 80 foot poles. The sketch below shows the arrangement schematically. A two bay system, forming a "W" requires four additional poles or a total of ten.

2nd Copied May 7/30

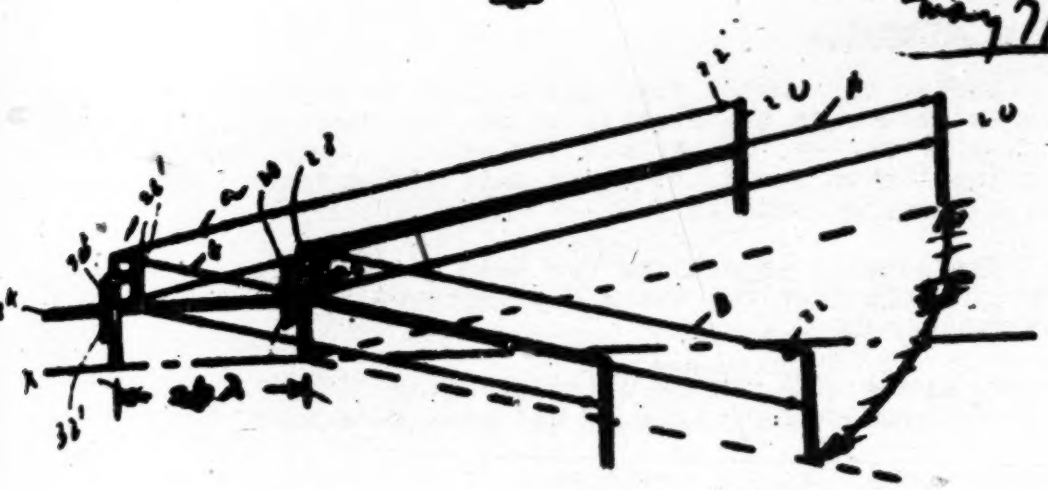


Fig 5

CHARACTERISTICS OF SYSTEM:

The two diagrams below show the theoretical curves of power distribution for one bay of this system in both the horizontal and vertical planes, the effects from ground being neglected.



Fig 6

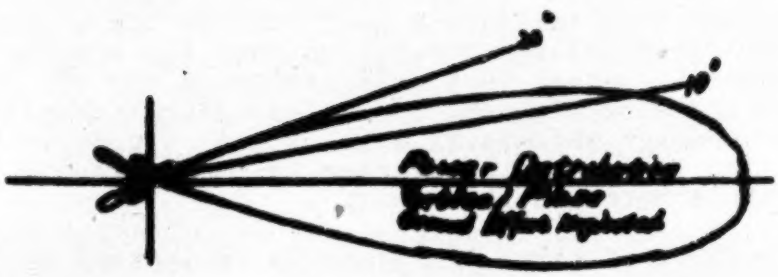


Fig 7

Carter
6705
N.Y. May 8, 1930
44/2

READINGS AT MARSHALL:

During the period from April 21st to May 1st, field intensity measurements were made at Marshall as we switched back and forth every five minutes between a doublet and the new antenna. During these tests the power input into the doublet and into the antenna was approximately the same, averaging about 13 K.W.

The general conditions for East to West transmission have been very poor the last few weeks but improved the last three days of these tests.

On April 21st and 22nd interference from the General Electric station at Oakland transmitting on the same wave made readings unreliable.

On April 23rd a large number of fair readings were obtained for the antenna but in all cases the doublet was either inaudible or too weak for accurate measurement.

The following day, April 24th, conditions were about the same excepting that readings for the antenna were extremely low at times.

On April 25th during the period from 11:30 to 8:40 EST the antenna readings were low but at all times measurable, while the doublet was at all times either inaudible or too weak to measure. However, from 8:40 until 5:00 when we stopped transmission reliable readings for both antenna and doublet were obtained.

On April 28th, 29th and 30th, we continued transmission until the signal had faded out at Marshall and on May 1st until 10:30 EDST at which time, we learned the next day, the signal had not faded out. On these last four days a large number of useful readings were obtained.

The results of the last five days readings are plotted on sheets which are attached. The curves are in terms of decibels gain with respect to one microvolt per meter. This system is used by the Bell Labs, and, after analyzing various methods of averaging results I am convinced that this method gives the most reliable results for average ratio to a doublet. It is equivalent to multiplying all ratios together and then taking the n-th root of the product (where n is the number of ratios) for the reason that the average logarithm of a set of numbers is equal to the logarithm of the nth root of their product. In this method high and low values of ratio have an equal effect upon the average whereas if arithmetical averages are taken one or two high ratios cause the average to be unreasonably high and very low ratios have little effect.

The results of these tests can be summarized as follows:

DATE	NUMBER OF USEFUL RATIOS	AVERAGE GAIN IN DECIBELS	PRODUCT	AVERAGE RATIO TO DOUBLET
Apr. 25	26	13.08	340	20.3
Apr. 28	74	17.74	1312	59.5
Apr. 29	72	18.70	1346	74.1
Apr. 30	66	19.20	1267.5	83.1
May 1	118	18.52	2184.4	71.1
TOTAL	356		6449.9	

OVERALL AVERAGE GAIN IN DECIBELS = 18.13

OVERALL AVERAGE RATIO TO DOUBLET = 65.0

DISCUSSION:

The resulting ratio obtained from these tests (65) is higher than expected. The calibration of the measuring device at Marshall has been checked and found to be OK. We can see no reason for the doublet not being efficient but we are putting up a new doublet further from the building for future tests. If we use a figure of 40 as a basis of comparison with other antennas we should be very much on the conservative side.

A close study of the curves will bring out several interesting facts:

In the larger proportion of the time the signals of the antenna and the doublet vary in synchronism. Allowance for the fact that the readings are taken five minutes apart should be made when these curves are scrutinized.

During these five days there are only two short periods where the antenna signal went so low as to become not measurable whereas the doublet signal was out a large number of times. One period when the antenna was out was during the eclipse of the sun in California. The other was in the early evening. Among several men in our company there is prevelent the idea that when a signal is out it is out regardless of the amount of power or of directivity used. These tests show the fallacy of this idea.

It will be noted that, in general the fluctuations in the received signal from the doublet are much greater than from the antenna. It is possible that this could be due to differences in directivity in the vertical plane.

COMPARISON WITH OTHER ANTENNAS:

A single bay harmonic antenna gives a ratio to a doublet of 16 and a two bay a ratio of 35. Using the conservative figure of 40 for one bay of the new Model D antenna the latter becomes 2.5 times as good as the one bay harmonic and 1.14 times as good as a two bay harmonic.

For operation at wavelengths around 35 meters it is proposed to build this new antenna 5 wavelengths long and thus do away with the necessity for intermediate towers and cross triatics. The directivity ratio for this length would be about 25. Such an antenna is one and one half times as good as a one bay harmonic. The one bay harmonic requires 10 towers costing $10,500 erected whereas the new type requires 6 towers costing $3,300. Thus we can obtain an antenna 60% better at a saving of $4200.

A two bay Horizontal Harmonic antenna requires 20 towers costing $21,000 whereas a two bay model D requires 10 towers costing $10,500 resulting in a saving of $10,500 in this case.

For wavelengths around 45 meters the savings would be greater.

"/4

For wavelengths below 25 meters this new antenna is to be built on 80 ft. wood poles. For these shorter wavelengths the new system can be built for less than one fourth the cost of the equivalent vertical harmonic antenna. A two bay vertical harmonic antenna for 17 meters costs about $20,000 whereas the new type can be built for less than $5,000, resulting in a saving of $15,000.

The new antenna requires considerably less land area than the equivalent horizontal harmonic antenna but somewhat more than that required for the two bay vertical model excepting in cases where adjacent antennas can be directed so as to make the most efficient use of land.

RECOMMENDATIONS:

We now have on schedule for Bolinas and New Brunswick five horizontal harmonic antennas. It is recommended that in place of these antennas we substitute the new model D antennas. Four of these antennas lie in the band between thirty and thirty five meters and the saving in tower costs would be $16,800. The fifth is for a wavelength of 43 meters and the saving on this would be $3400. This makes a total saving on the five of $23,200. There would also be some additional saving due to the doing away with the cross triatics and rigging used in the harmonic antennas.

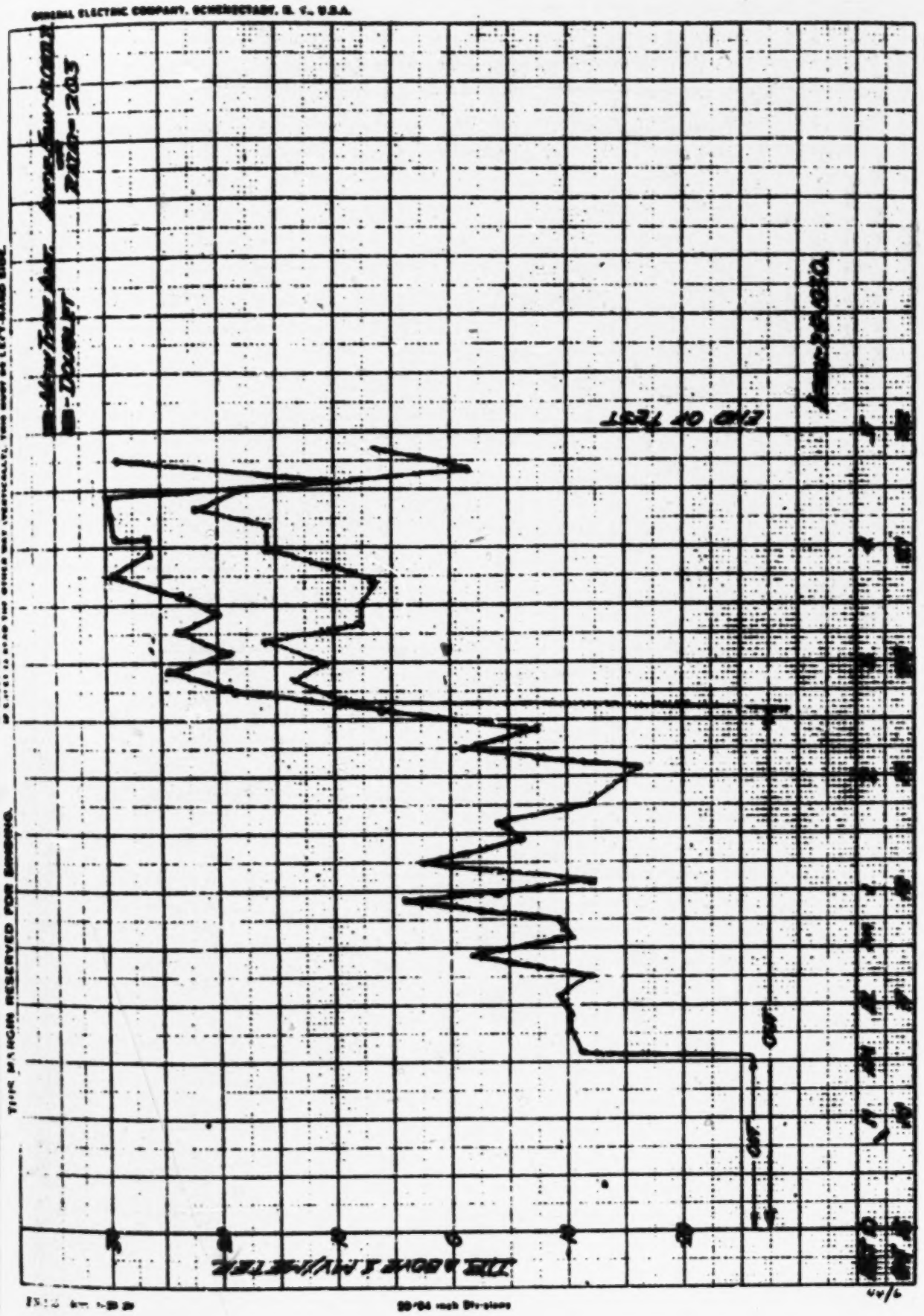
There are also on schedule six one bay vertical harmonic antennas, three for Bolinas and three for New Brunswick. If we substituted the new type in place of these we would have in each case an antenna two and a half times as good for less than half the cost resulting in a saving of about $30,000. However, before recommending such a change, particularly at Bolinas, a study of available land space should be made.

I believe that towers for these jobs are now on order. If such is the case the towers saved by the change can be used for either additional antennas or additional bays.

Copies to Mr. Taylor.
Brenza
Thompson
Hallborg
Harnall
Patent Dept. (Mr. Jumiks)

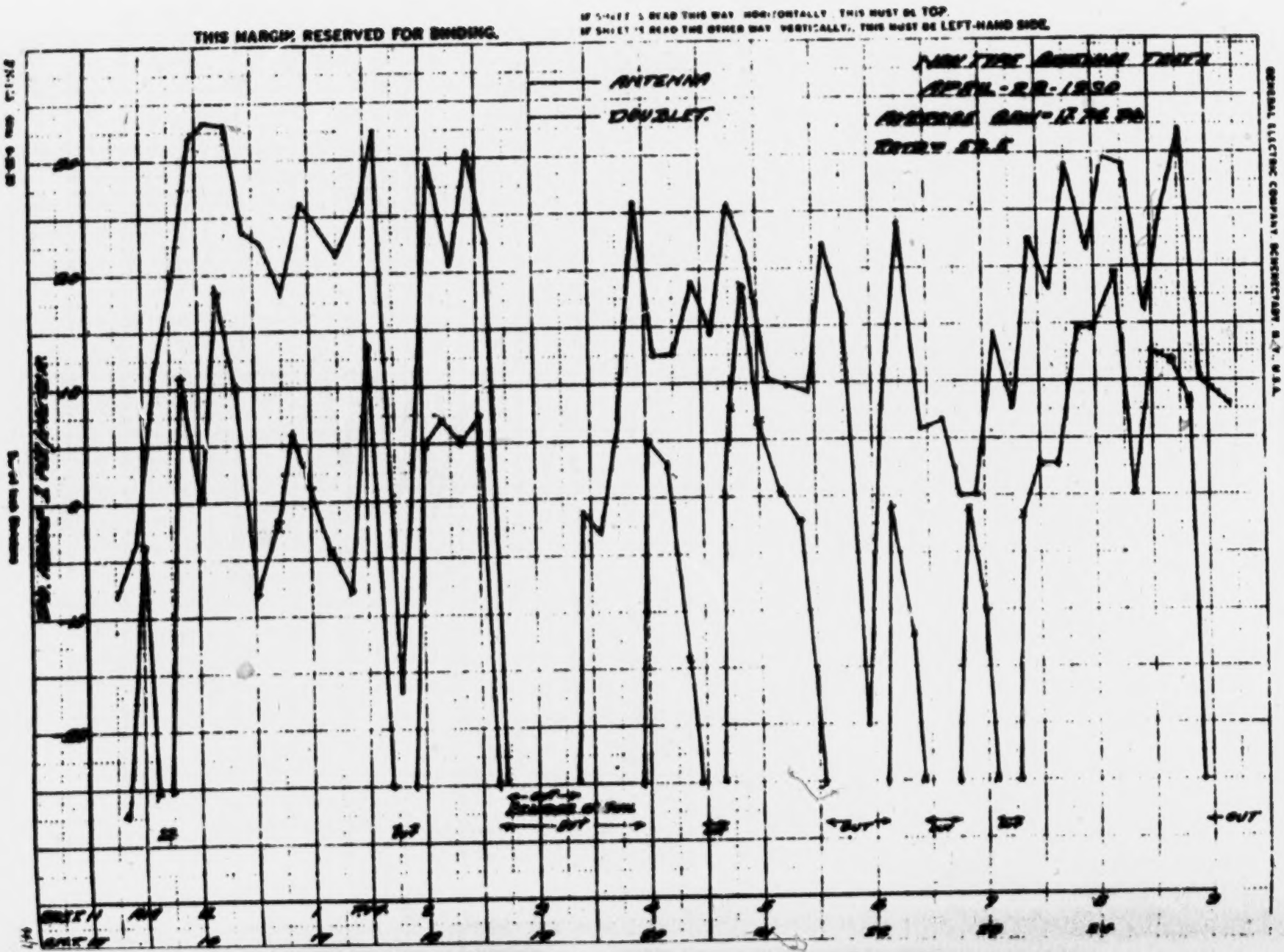
Rocky Point, New York
May 6, 1930
P. S. Carter
P. S. Carter.

H.H. May 8, 1930

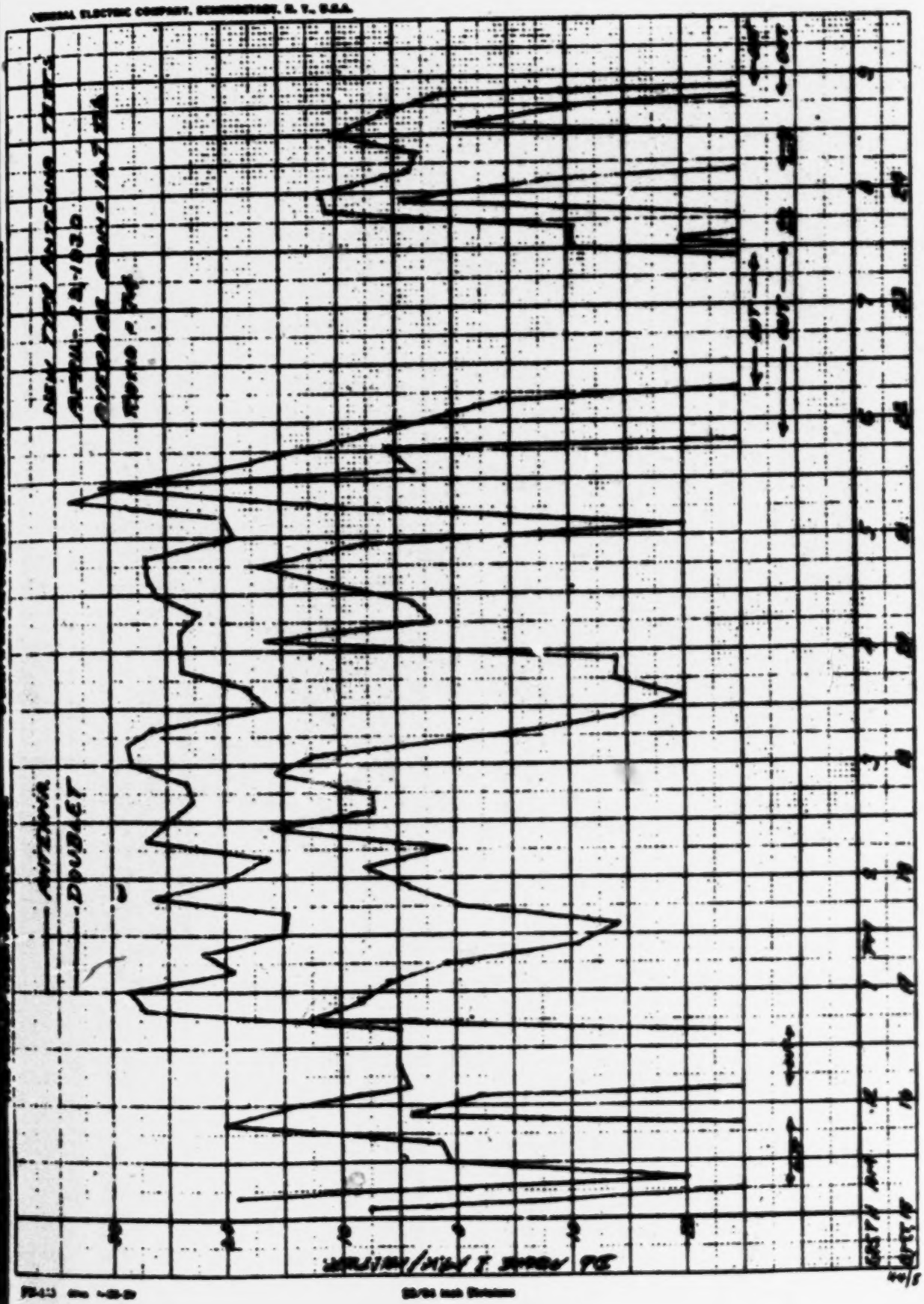


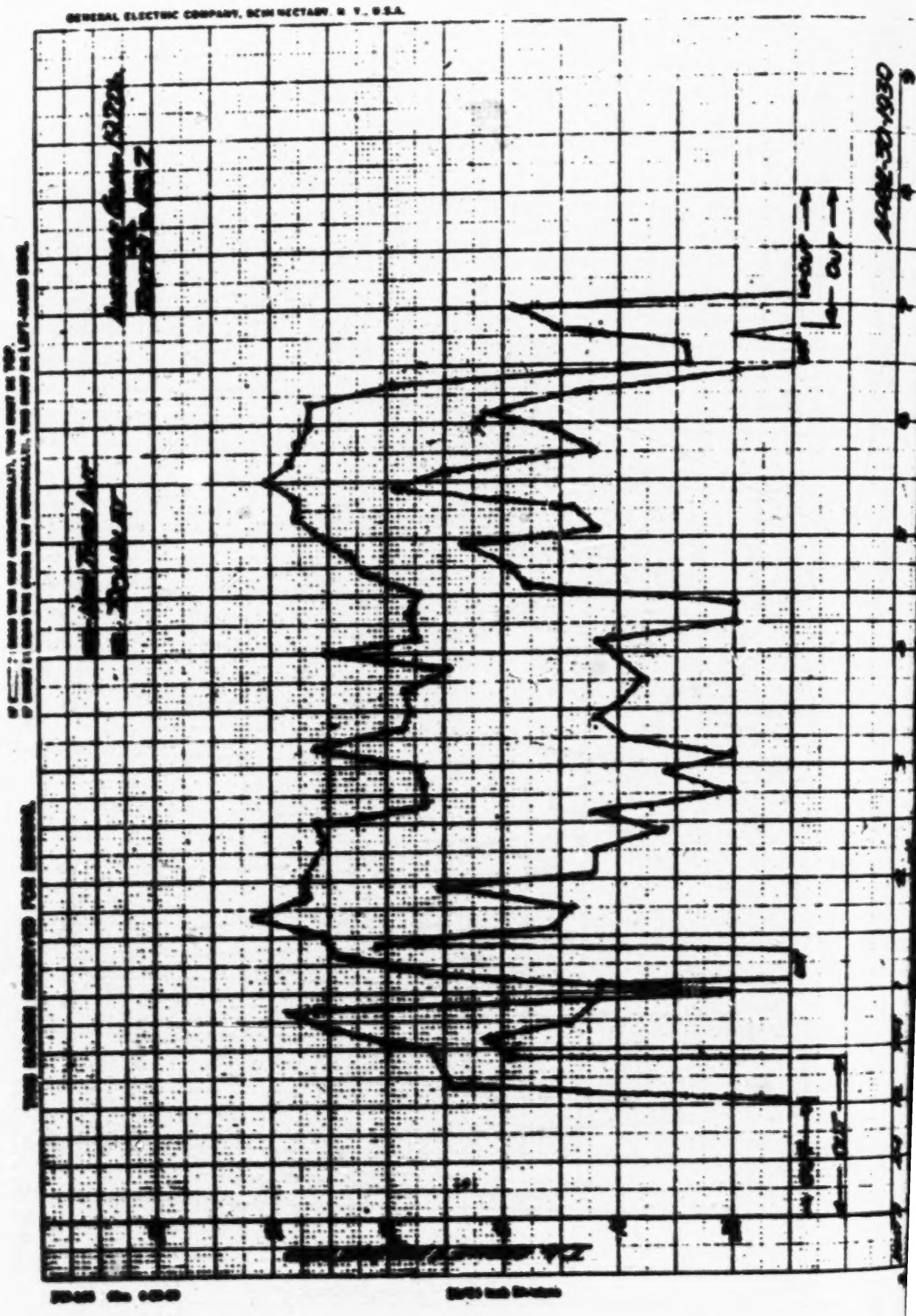
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ANT. DEV. ANTENNA TEST
ANTENNA AN-1030
RADIO 2 PAT
AIRCRAFT CONFIGURATION
ANTENNA
DOUBLET
3d PRIME 1 MIN/MEASURE



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PLAINTIFF'S EXHIBIT No. 46

RD-1009

Mr. H. B. Morris
Mr. P. S. Carter

March 22, 1930
RD-1009

Experimental Antenna (New Type)

Dear Mr. Morris:

We appreciate the cooperation obtained from Mr. Ash and the men working under his supervision in connection with this job. Considering the fact that this antenna has been constructed almost entirly from reclaimed material and with incomplete drawings, the completed job is very satisfactory both in appearance and workmanship.

Yours very truly
P. S. Carter
P. S. Carter

PSC/MVH
Cc Mr. C. W. Hansell

PLAINTIFF'S EXHIBIT No. 46

Improved type directional antenna 1.

This idea in mind for last three or four months but not worked up until yesterday. After analysis find much cleaner pattern than ordinary harmonic antenna and probably considerable superiority. Has advantage of being much simpler, stagger eliminated, and only takes 6 poles for equivalent of 2 bays whereas horizontal harmonic take 20.

The fundamental unit is a harmonic wire of one half wave total length arranged in V and fed at apex as shown in Fig 1. This gives characteristic of form Fig 2 in plane of Fig 1.

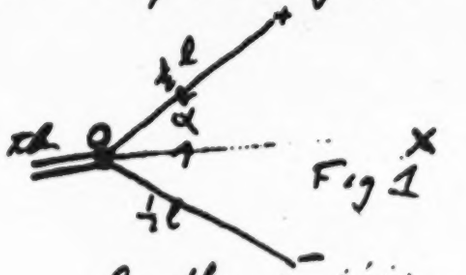


Fig 1

l = odd number of half waves angle α is determined by length of half


Fig 2.

At ½λ below this unit is suspended a similar unit in plane to cancel radiation below and above as shown in fig 3. In order to cancel back radiation a similar unit to Fig 3 is placed behind any odd number of quarter waves and fed leading in phase by same number of quarter places as distance behind

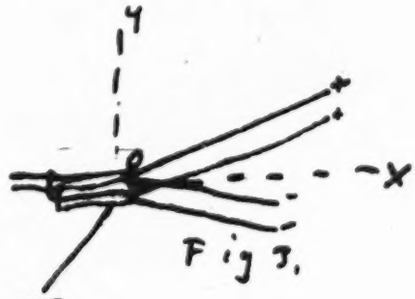


Fig 3.

continued

Witnessed by Nov 27 '29
W. E. Wallace

711
904

measured in number of quarter wavelengths.
See Fig 4.

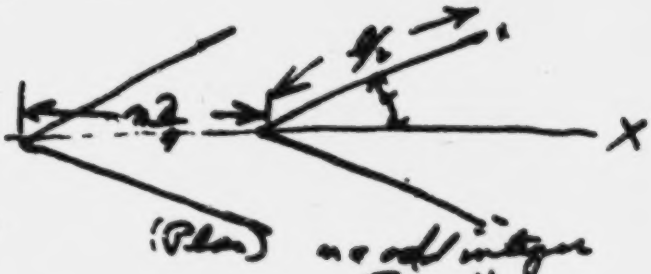


Fig. 4

Angles for maximum
lobes for various lengths
of wire are:

Total wire length in wavelengths	angle	length in wavelengths
6 1/2	28.3°	3 1/4 λ/3
8 1/2	24.4°	4 1/4
10 1/2	21.9°	5 1/4
12 1/2	19.9°	6 1/4
14 1/2	18.4°	7 1/4
16 1/2	17.2°	8 1/4
20 1/2	15.5°	10 1/4
24 1/2	14.1°	12 1/4
32 1/2	12.2°	16 1/4

Directive pattern in plane of Fig 4 with reflector is given by

Power $\propto A_1^2 + A_2^2 - 2A_1A_2 \cos\left(2\pi\frac{l}{\lambda}\sin\alpha\sin\theta\right)$

where θ is angle to X axis, A_1 is amplitude due to one half wire computed as function of $(\theta - \alpha)$ and A_2 is amplitude due to other half as function of $\theta + \alpha$. This characteristic fairly complete for

(continued)

Witness his
A. E. Goldstine

Nov. 22, 42

A. form of Syst. directive Antenna. 3.

This system can be extended to an array of several units like Fig 5. to increase directivity by obtaining by odd quarter waves along line X X' and any number of such systems can be placed side by side.



Fig 5.

Nov 27 '29

Witness by H.E. Shelton P.A.C.

44/

PLAINTIFF'S EXHIBIT No. 47

M. Harry Tunick.
Patent Department
Docket 4205

Mr. H. H. Beverage
Mr. C. W. Hansell

May 7, 1930
RD-1009 - Tests of New Directive Antenna (Model D)

PATENT DEPARTMENT
RECEIVED
MAY - 8 1930
Answered

Dear Mr.Beverage:

Attached you will find Mr. P. S. Carter's report on the results of tests recently made on a new type of directive transmitting antenna which he devised. As you will note from this report, the new type of antenna seems to be a decided improvement over the model B and C harmonic projector antennas. Its advantages are due to its improved directivity and a reduction in the number of poles or towers required to support it.

Although it is proposed to continue the tests by transmission on about one day each week for an extended period we believe the data already accumulated together with a consideration of the type of directivity obtained make it safe to recommend the new antenna for immediate commercial use. It is therefore suggested that consideration be given to substituting the new antenna for the original harmonic types in the present construction programs for Rocky Point, New Brunswick, Bolinas, Kahuku (Telephone) and other places.

The total net out of pocket cost of developing this antenna has been only about $3500 if we take out the second hand value of the material which we have left.

The total saving over the harmonic type of antennas, if all the new transmitters now scheduled were equipped with the minimum recommended directivity, would amount to at least $3,500,000. Therefore, we are confident that the value of this development is at least 1,000 times its out of pocket cost and is probably 500 times its total cost after adding incidentals and overhead.

The value of this one detail development in reducing construction costs should be sufficient to pay all salaries and field expenses for the whole Rocky Point Development force for a period of about six years.

Yours very truly
C. W. Hansell
C. W. Hansell

H.H. May 8 1930

GWH/MVN
Cc Mr. C. H. Taylor
Mr. H. H. Beverage
Mr. J. H. Shannon
Mr. H. E. Wallborg

Mr. P. S. Carter
Mr. Harry Tunick (Patent Dept.)

PLAINTIFF'S EXHIBIT No. 48

RD-1009

Mr. H. H. Beverage
Mr. C. W. Hansell

March 21, 1930
RD-1009

Comparison Tests on New Type of Harmonic Antenna

Dear Mr. Beverage:

We have just completed the construction of a modified type of horizontally polarized harmonic wire antenna which was suggested by Mr. P. S. Carter. If this antenna proves to be efficient, it should effect a considerable saving in construction costs in many cases by reducing the number of poles or towers required to support the radiators.

This antenna model is now being tuned up and checked by local measurements. As soon as this local work is finished we would like to make a comparison test between it and a plain doublet antenna for transmission to Marshall, California. In making these tests we would expect to follow the same procedure we have previously used for similar tests in which we alternated from one antenna to another at 5 minute intervals. For each interval we would send the number of the observation for signal strength reading so that Marshall could report the results of observations by reading numbers and thus avoid the possibility of a confustion in time. The frequency for which we have designed the antenna is 17,300 K.C. and we will use this frequency for making the comparison tests. We will use the call letters WEXT.

According to present indications, we will be ready to start the tests some time during the week of April 7th to 12th and will wish to continue observations for a period of at least three days. We would like to have the results of each day's tests reported back by service message as rapidly as possible. At the end of the three day period we would decide from the results obtained whether to continue testing or to discontinue temporarily for making modifications to the antenna. Probably we would wish to continue the test for a considerable period by transmitting one day each week for several months so that we could be sure that the results obtained were reliable and not due to some temporary atmospheric condition.

Could you please make arrangements with Mr. R. R. Beal to have his men at Marshall cooperate with us in making the tests? We will advise Marshall by service message the exact date on which we wish to start the tests.

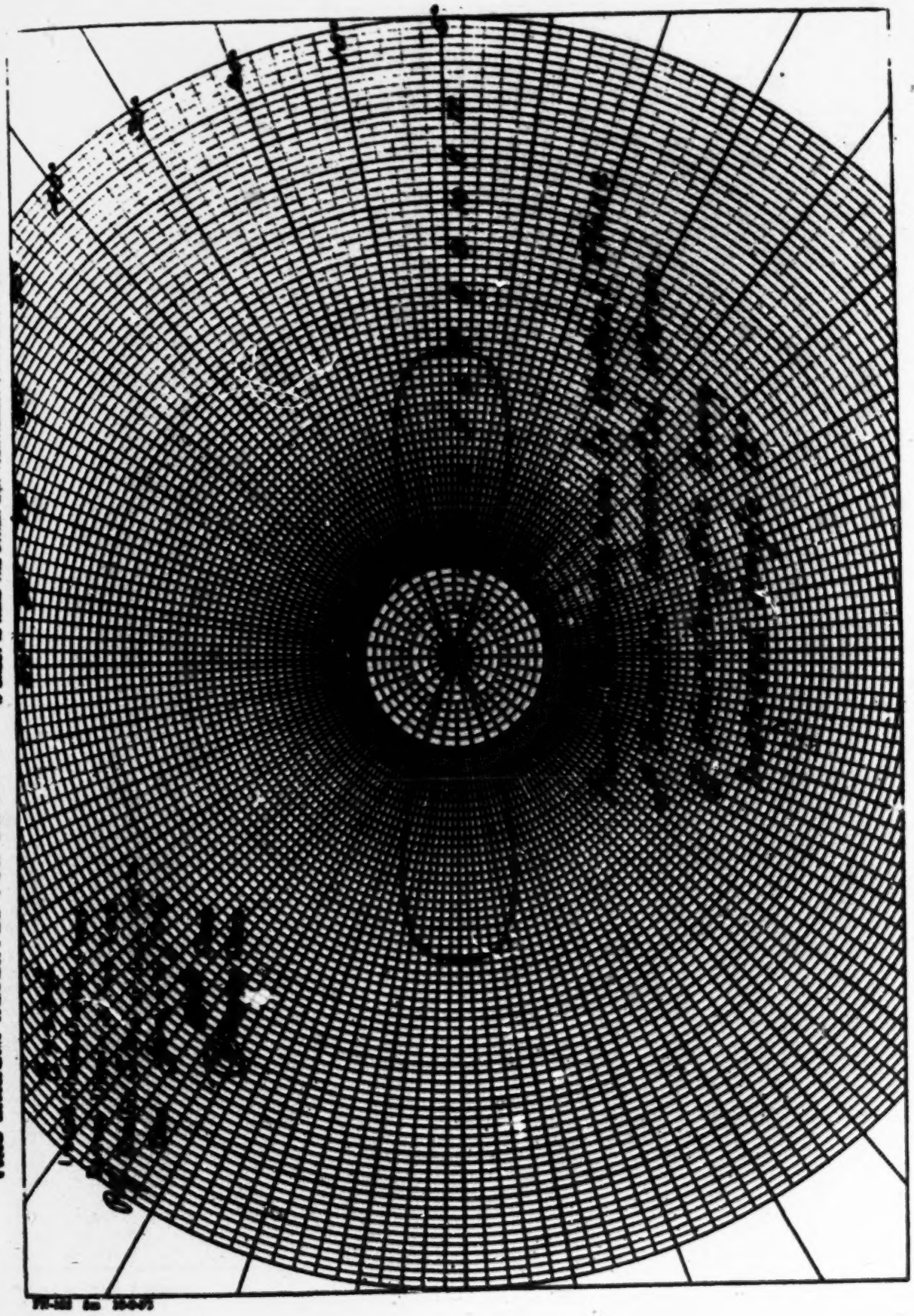
Yours very truly

C. W. Hansell

CWH/MVN
Cc Mr. C. H. Taylor

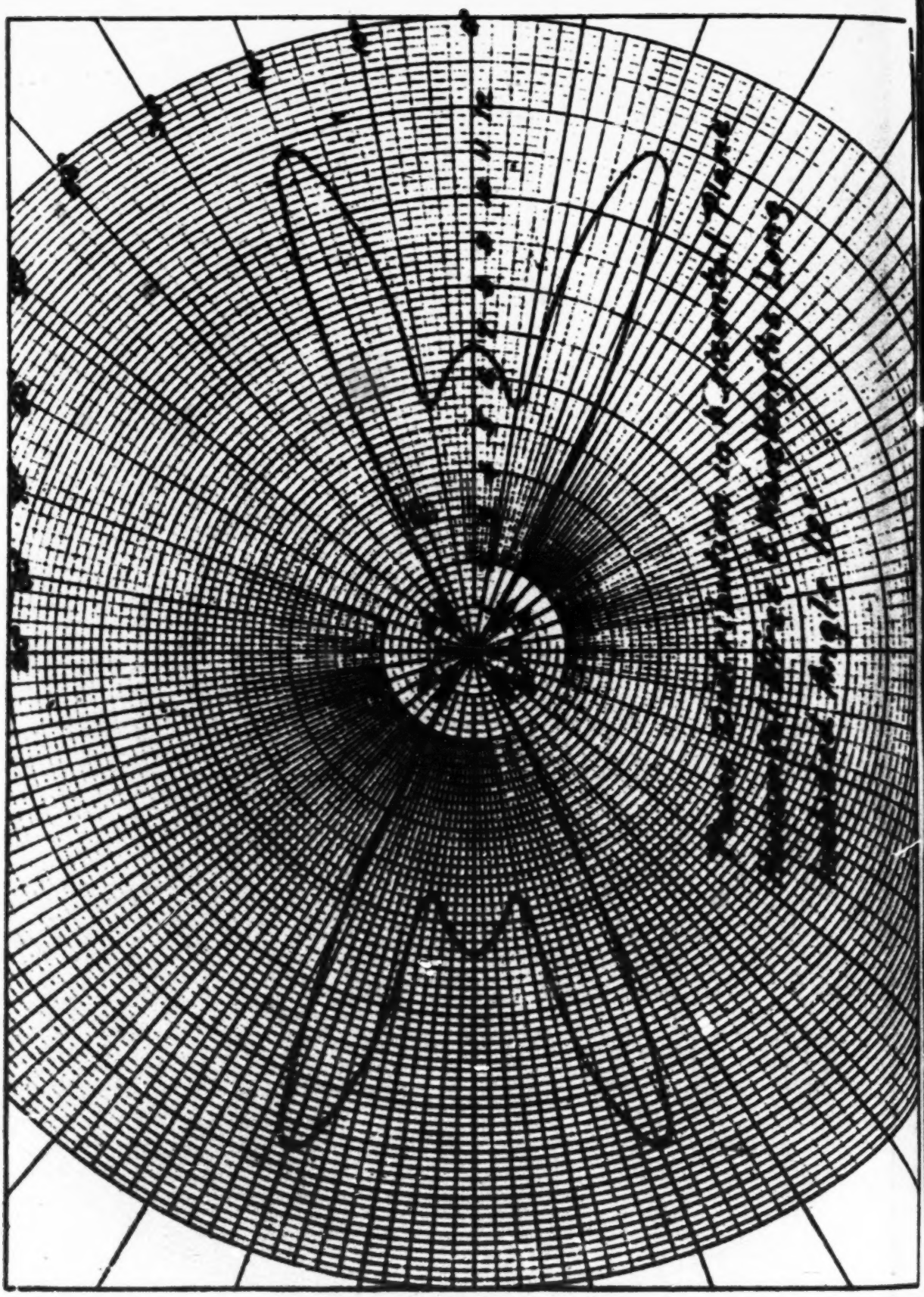
FIELD INTENSITY PATTERNS OF AN ANTENNA COMPOSED OF TWO QUARTER WAVELENGTHS WIRES AT VARIOUS ANGLES.

PLAINTIFF'S EXHIBIT No. 52

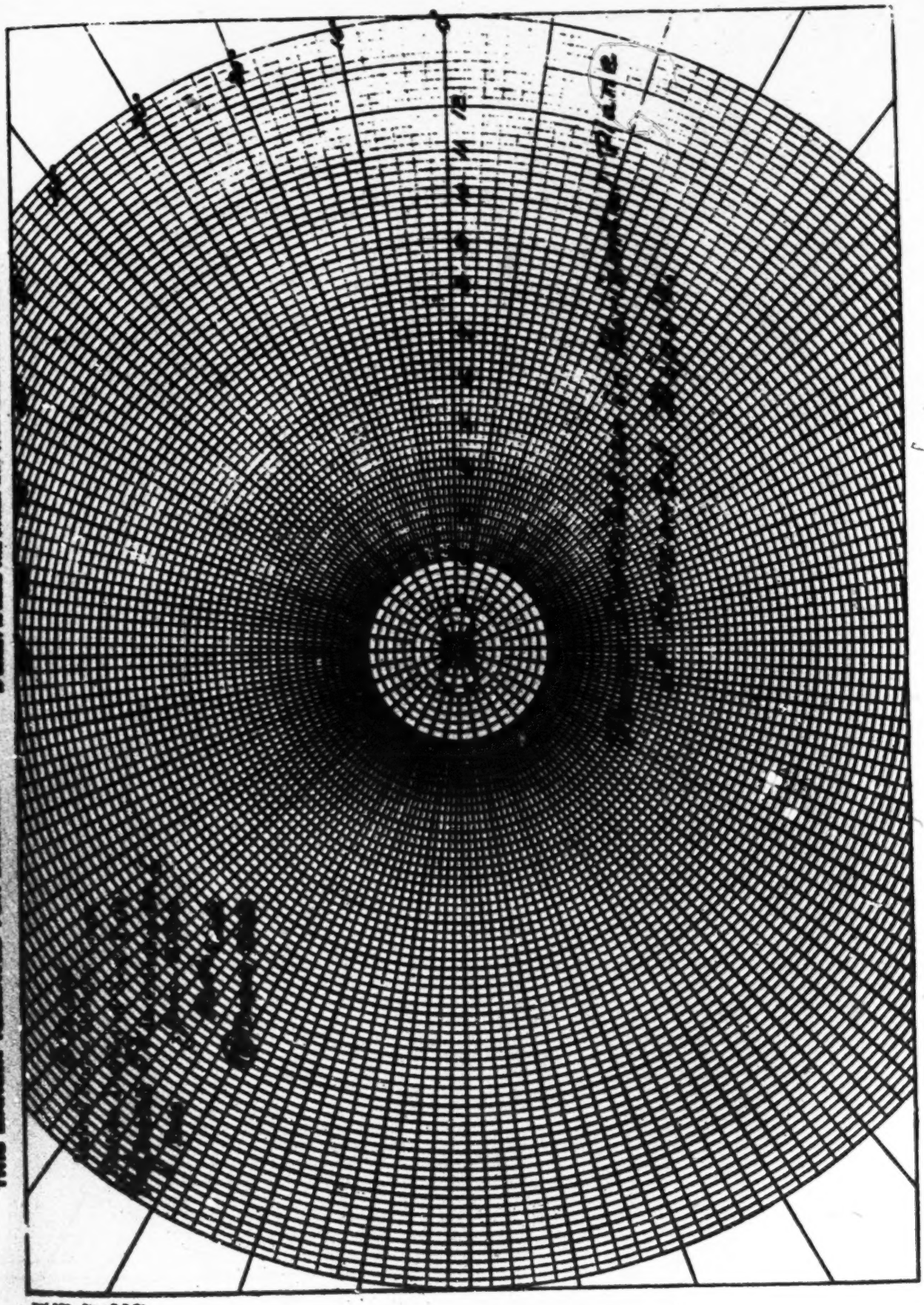


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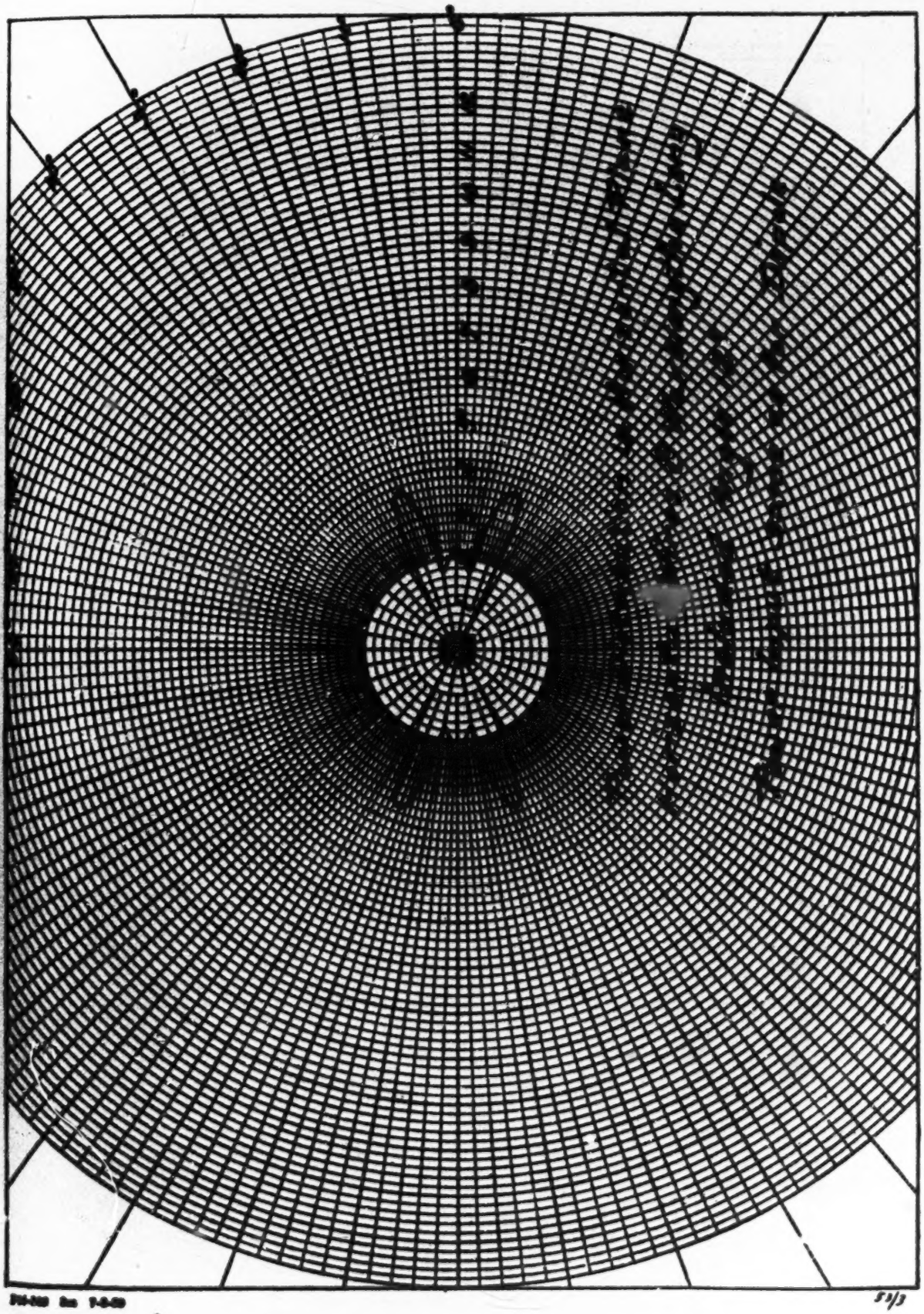
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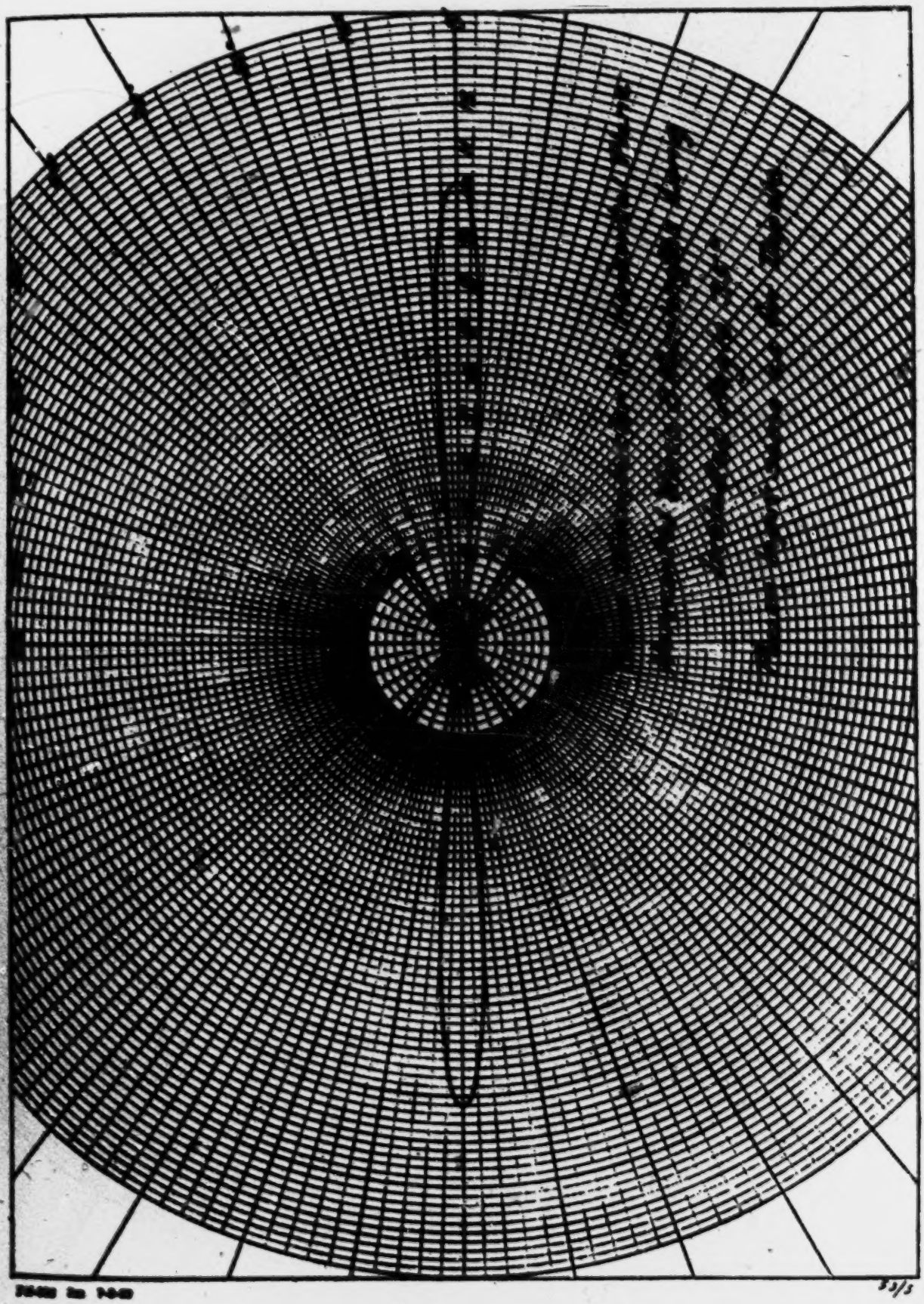
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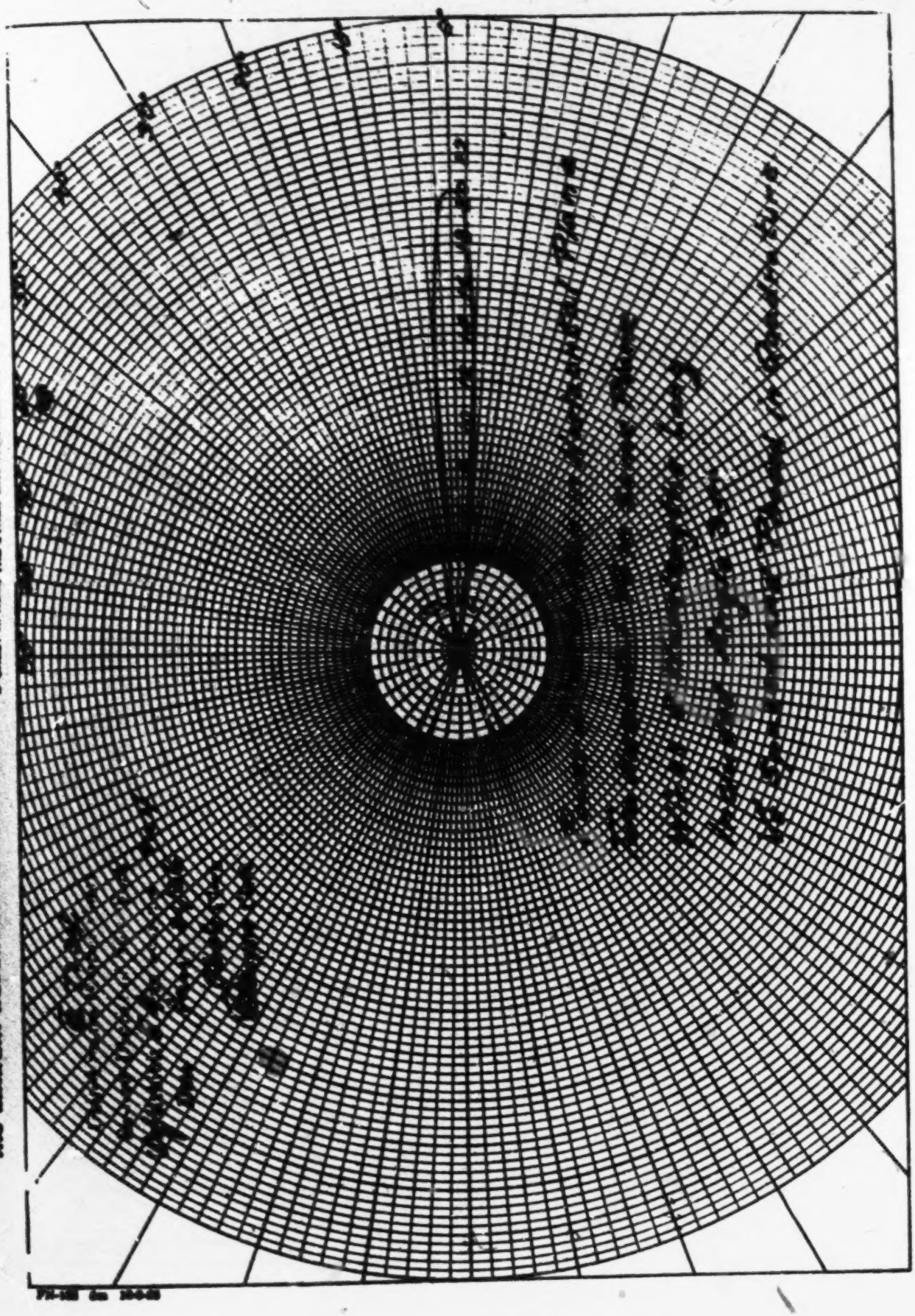


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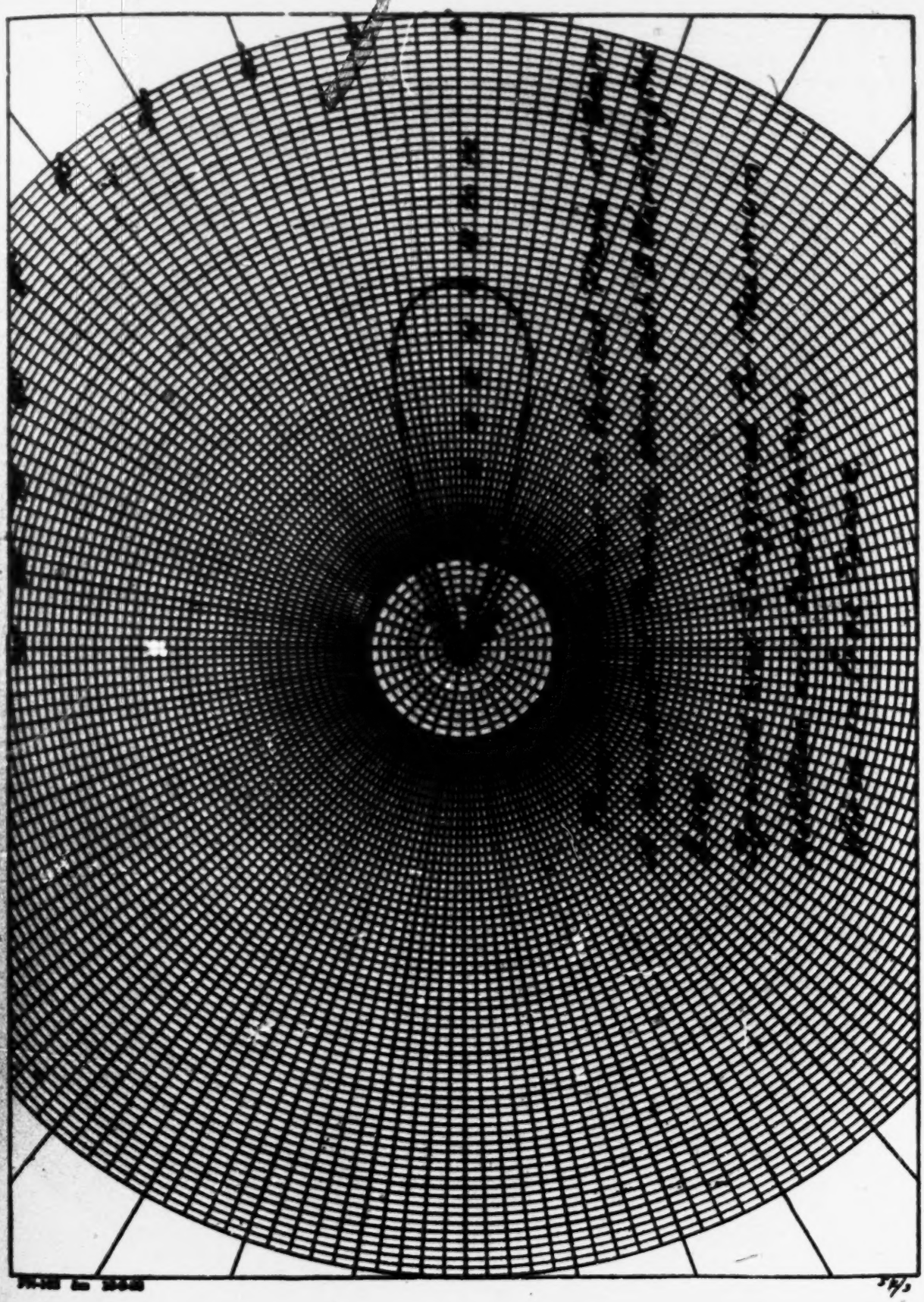
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PLAINTIFF'S EXHIBIT No. 54



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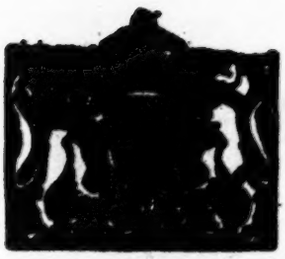
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PLAINTIFF'S EXHIBIT No. 55

Plaintiff's Exhibit 55

Plaintiff's Exhibit 55 is a certified copy of an application for Letters Patent of the United States for "Improvement in Horizontal Vee-Type Antenna", filed by or on behalf of Edmond Bruce on February 3, 1931, bearing Serial No. 513,063. The British patent No. 392,201, issued to assignees of Edmond Bruce (constituting plaintiff's Exhibit 41 and reproduced above), was issued upon an application filed in Great Britain under the Convention and corresponding to the above-mentioned U. S. application Ser. No. 513,063 (plaintiff's Exhibit 55).

PATENT SPECIFICATION



Convention Date (France): April 29, 1924. **233,346**

Application Date (in United Kingdom): April 29, 1925. No. 11,179/25.

Complete Accepted: July 29, 1926.

COMPLETE SPECIFICATION.

Improvements in or relating to Directive Aerials.

I, LUCIEN LEVY, of 66, rue de l'Universite, Paris, France, a citizen of the Republic of France, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The general type of aerials hitherto used is constituted by one or several conductors disposed in space and connected to one pole of one or several generators of high frequency currents, the other pole of which is connected to earth or to one or several wires constituting a balancing element. In certain cases, the wires of the aerial or those of the balancing element are connected by transverse wires which connect equipotential points together.

In these conditions, the aerial radiates a vertical electrical field which is accompanied, during its propagation, by earth currents which give rise to losses of energy.

In order to avoid these losses, it has been suggested to radiate the energy by means of vertical aerials comprising several wave lengths; in these conditions, the aerial radiates energy in the space comprised between two conical surfaces, the angle at the apex of which is less than 90°, and having the aerial for their axis.

In the case of ordinary aerials, if graphs are drawn with the distance from the ground of any point on the aerial as abscissa and the aerial current at that point as ordinate, one obtains either a curve or a cylindrical surface, that is, a surface generated by a curve remaining parallel to itself.

The present application has for its object improvements to aerials for the purpose of obtaining a more intense radiation of energy towards the receiving station, and to enhance the propagation of this energy with a minimum of loss.

According to this invention I provide a process for the emission at great distances of Hertzian radiant energy, characterised in that short waves are emitted (of wave length less than 1000 metres) with a horizontal electric field adapted to enhance reflection without loss on the Heavyside layer and on the ground and the propagation through space, the energy given out being maximum in the vertical plane perpendicular to the axis of the radiator, and being emitted in the form of an inclined pencil having the said plane for plane of symmetry.

For this purpose I use aerial comprising two coplanar or colinear horizontal surfaces or groups of wires, connected to opposite poles of the generator at their inner ends, and fixed above the ground at a height of the order of from $\frac{1}{8}$ to $\frac{1}{4}$ of a wave length.

In the radiating surface (planes, for example) the current distribution is such that if one plots as ordinates, at every point of the surface, the current at that point, surfaces other than cylindrical surfaces are obtained. In other words, the surface being connected at two points to a high frequency source of potential difference, the current propagation takes place in two dimensions.

Owing to this double propagation, the directive action of the aerial is much greater, and instead of conforming to a three dimensional polar diagram in the shape of an anchor ring, as with ordinary aerials, the radiation takes place along a pencil only.

By the use of emitting aerials with a radiated electric field which is horizontal

instead of vertical, a more pronounced directive effect is obtained and the losses during the propagation are lessened.

A point extremely important, which necessitates the use of a horizontal electric field, is that the transmission of waves of short wave length to a great distance appears to take place by reflection on the Heavyside layer. It is easy to see that a polarised wave with a horizontal electric field is reflected without loss of energy on a horizontal conducting plane, while, on the contrary, a wave with a vertical field may fall under the incidence of Brewster, and in this case the reflected energy is much reduced. It is therefore logical to think that "fading" will not occur for waves with a horizontal electric field. Finally, it is proper to note that the atmospherics are very weak on a horizontal frame, consequently waves with a horizontal electric field must be particularly favourable for the elimination of parasites.

Horizontal aerials have already been utilised, but these aerials were employed with a large wave length and generally placed relatively very close to the ground and were of very large dimensions. The invention on the contrary, concerns the use of horizontal aerials of very small dimensions for the emission of waves of short wave length, situated at a height which is a considerable fraction of the emission wave length ($\frac{1}{4}$ wave, for example). Owing to this height and to the horizontality of the electric field, the losses in the neighbourhood of the emitting aerial are considerably reduced.

It is extremely important to raise the horizontal aerials to a suitable height, greater than $\frac{1}{4}$ of the wave length of the emitted wave. The effect of the conducting earth is to give an image of the aerial. If the aerial is in the neighbourhood of the ground, this image, which radiates a field inverse to that radiated by the aerial, partially neutralises the effect at a distance of the aerial. This drawback is avoided when the height of the horizontal aerial is comprised between $\frac{1}{4}$ and $\frac{1}{2}$ of the wave length. In this case, the radiation of the image and of the aerial are superimposed. It is easy to calculate, besides, the inclination to the horizontal plane, of the pencil of maximum energy density. These effects take place owing to the combination at a distance of the radiation of the aerial and of its image, the currents of which are out of phase by a quantity which depends on the height at which is placed the horizontal aerial. It must be noted that a reflecting element constituted by a wire, placed at the surface of the ground, will permit the phase of the currents radiated by the image and the inclination of the pencil of maximum energy density to be varied as may be desired.

The radiation takes place, in these horizontal aerials, laterally and perpendicularly to the direction of the aerial when the latter is of the type employing a one-dimensional conductor, and obliquely in the plane of symmetry of the aerial when a radiating surface is employed, as distinct from a linear radiator.

Referring to the accompanying drawings, which illustrate as an example a manner of carrying out the invention:—

Fig. 1 shows one method of realising an elevated horizontal aerial according to the invention;

Fig. 2 is a graph showing the distribution of the currents in the aerial shown in Fig. 1;

Fig. 3 represents a horizontal radiating surface;

Fig. 4 is a plan view of the aerial 5—5—7—7 showing diagrammatically the formation of the waves;

Figs. 5, 5^a, 5^b, illustrate the arrangement of wires in a series constituting a conductor;

Fig. 6 shows in perspective the aerial 5—5—7—7;

Fig. 7 shows an alternative arrangement;

Fig. 8 illustrates the use of two planes adapted to act as electric reflectors.

The aerial shown in Fig. 1 is constituted by the plane consisting of horizontal wires 1 and 2 supported between pillars 3 and 4 by spreaders 6 and 8 insulated from the live wires by insulators 5 and 7. The wires 1 and 2 are connected by chains 14 of insulators. A high frequency generator 11 supplied the energy to the aerial, at the points 12 and 13, by means of the pair 9—10.

Although at a first glance this aerial appears similar to the vertical T-shaped aerial, it is totally different therefrom inasmuch as the two branches of the T are insulated from each other.

In operation, the arrangement functions as follows:

The wires 9 and 10 of the feeding-line are the seat of high frequency currents in inverse direction, according to the arrows 16 and 17, and, consequently, the vertical radiation of the pair 9—10 is nil. The portion 1, 2 alone radiates, laterally and in the direction 15, a horizontal electric field *h* and a magnetic vertical field H.

The reception of these waves which

have a horizontal electric field can be made on a horizontal aerial, disposed in a parallel direction to the field *h* and which can be either elevated or at ground level. Owing to the inclination of the magnetic field to the direction of propagation, vertical or horizontal aerials directed in a perpendicular direction to that referred to above can be also used.

If a receiving frame is used, this must be generally placed in a horizontal plane, but reception will also be possible on a vertical frame placed perpendicularly to the direction from the emitting to the receiving station.

In Fig. 2, at each point of the wires 9, 10, a perpendicular has been plotted, proportional to the current at that point at a given instant.

It is seen that the length of the pair 9—10 is half a wave length and that the lengths of the portions 1 and 2 are a quarter of a wave length. Other distributions could have been chosen besides the one above described. Any desired distribution can be obtained by suitably combining with the aerial artificial line elements. Particularly, any particular distribution can be avoided by constituting each of the conductors 9 and 10 (or even 1 and 2) by series of wire elements constituting capacities disposed in succession to one another.

Fig. 5 illustrates an arrangement in which the conductor is composed of a series of overlapping wires a, a^1, a^2 . . . . . ;

Fig. 5^a shows an arrangement in which the elementary wires a, a^1, a^2 . . . . . are spaced end-on, and Fig. 5^b shows an arrangement in which the elementary wires a, a^1, a^2 . . . are separated by capacities b, b^1, b^2 . . . . .

Figs. 3 and 6 illustrate an aerial formed as a horizontal surface which radiates waves with a horizontal field and forming a pencil with a direction inclined to the horizontal, thereby obtaining, in one of the emission surfaces, the distribution of current shown by the graph of Fig. 4. In Fig. 6 this surface is represented in perspective and radiates its energy in the direction of the arrow 19 with a maximum of radiation in the vertical plane of symmetry 20.

The radiating surface is supported by the four pillars 3, 3 and 4, 4, by means of the four insulators 5, 5 and 7, 7. The generator 11 puts in a high frequency current at the points 12 and 13. If the current intensity at any point along 5—7 and 5—5 is plotted as ordinates (Fig. 4), curves 23 (each of a quarter wave length) and 24 (two loops d and d^1 of a quarter wave length each) are obtained, and similarly along line 7—7. It follows that the high frequency currents proceed on the surface 5—5—7—7 in such a manner that a half wave length regime 16—17 is established (formed of the two quarter wave lengths 23) and travels from front to back (arrow e) along the depth of the plane 5—5—7—7. The dimensions of the phase from front to back are such that the propagation from front to back comprises several quarter wave lengths. In a similar manner, the front to back propagation on 5—5 comprises several quarter waves d, d^1, and this propagation occurs along the whole breadth of the plane of the aerial. A double stationary regime is therefore present, a half wave length one, parallel to the arrows 16, 17, and another of several quarter wave lengths, parallel to the arrows 21 and 22.

Owing to the propagation in the direction 16, 17, the radiation energy is concentrated in the plane 20 and owing to the propagation in the perpendicular direction, it is limited to a pencil inclined to the horizontal. It is easy, besides, to adjust the inclination of the pencil by varying the distribution parallel to the plane 20 (Fig. 3), for example by inserting inductances or capacities placed at ground level, connected to the surface by conductors parallel to 9 and to 10. Fig. 7 shows this variation in which inductances or capacities f or impedances x are inserted in the conductors connecting the aerial to earth.

It should be mentioned that the radiating surfaces may comprise a larger number of principal axes according to which the propagation takes place, notably one could contemplate three axes forming a trihedron; one can in this manner obtain radiating beams as fine as desirable.

Similarly, these surfaces may be disposed in any direction and may radiate an electric field of any inclination; they can also act as reflectors. As an example, Fig. 8 shows the use of two planes g and h, perpendicular to the aerial, and adapted to act as electric reflectors.

The use of the arrangements described above is applicable to all wave lengths, but it should be pointed out that their results are particularly important for short wave lengths, less than 1000 metres in length, notably for wave lengths of 100 and 200 metres. The radiating planes could also be constituted by groups of metallic tubes or any other conductors.

Having now particularly described and ascertained the nature of my said inven-

tion and in what manner the same is to be performed, I declare that what I claim is:—

1. A process for the emission at great distance of Hertzian radiant energy consisting in the emission of short wave length (less than 1000 metres) with a horizontal electric field permitting the reflection of the energy on the Heaviside layer with a good efficiency by means of an aerial stationary with respect to the earth, comprising two co-planar or co-linear horizontal surfaces or groups of wires connected to opposite poles of a high frequency generator at their inner ends and fixed above the ground at a height of at least $\frac{1}{4}$ of a wave length.

2. In a process for the emission at great distances of Hertzian radiant energy, as claimed in Claim 1, an aerial as claimed in Claim 1, in which the length of each co-planar or co-linear element is a quarter wave length or a multiple thereof.

3. In a process for the emission at great distances of Hertzian radiant energy, as claimed in Claim 1, an aerial as claimed in Claims 1 and 2 in combination with a reflector, placed at ground level and parallel to the aerial.

4. In a process for the emission at great distances of Hertzian radiant energy as claimed in Claim 1, an aerial as claimed in Claims 1 and 2, in combination with vertical frames perpendicular to the direction joining the sending and the receiving stations.

5. In a process for the emission at great distances of Hertzian radiant energy, as claimed in Claim 1, the aerials, substantially as described and as illustrated in the accompanying drawings.

Dated this 31st day of March, 1925.

MEWBURN, ELLIS & Co.,
70/72, Chancery Lane, London, W.C. 2.
Chartered Patent Agents.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1926

233,346 COMPLETE SPECIFICATION

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1

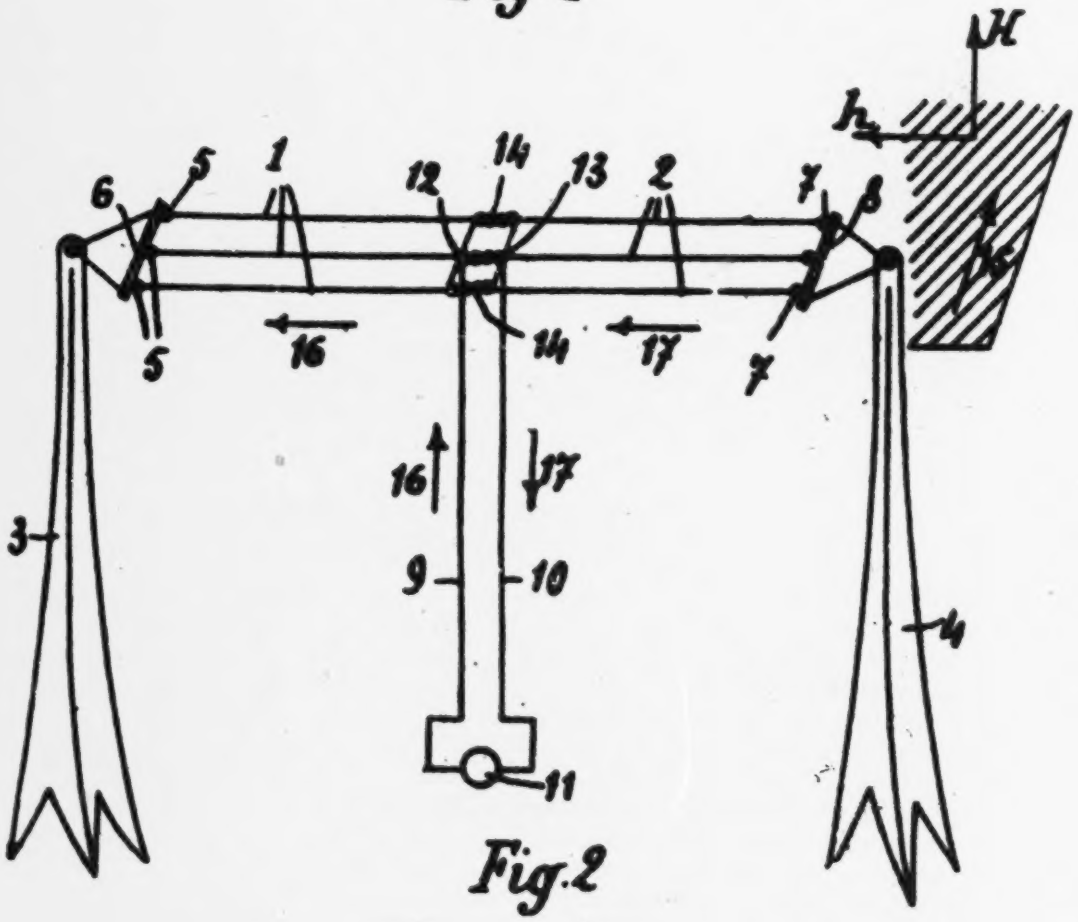
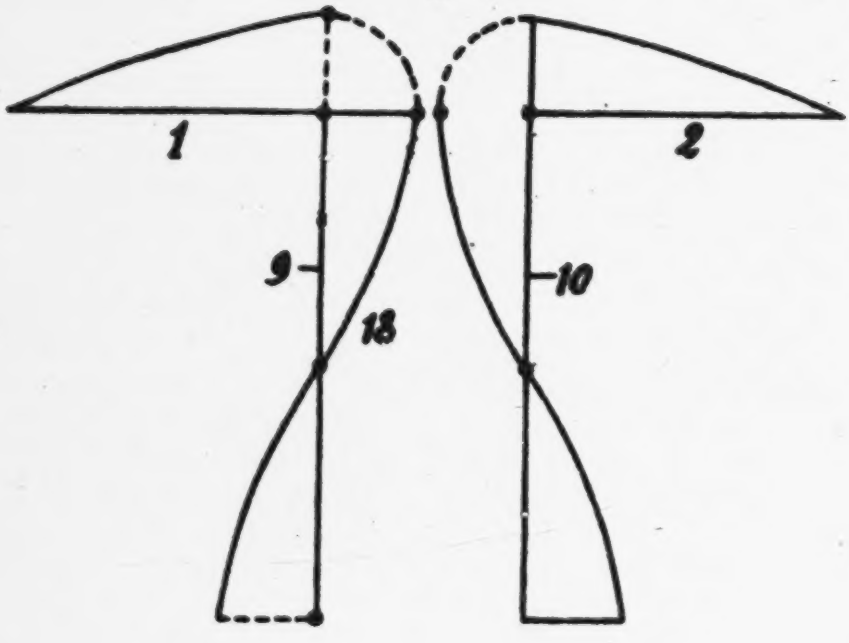


Fig. 2



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Fig.3

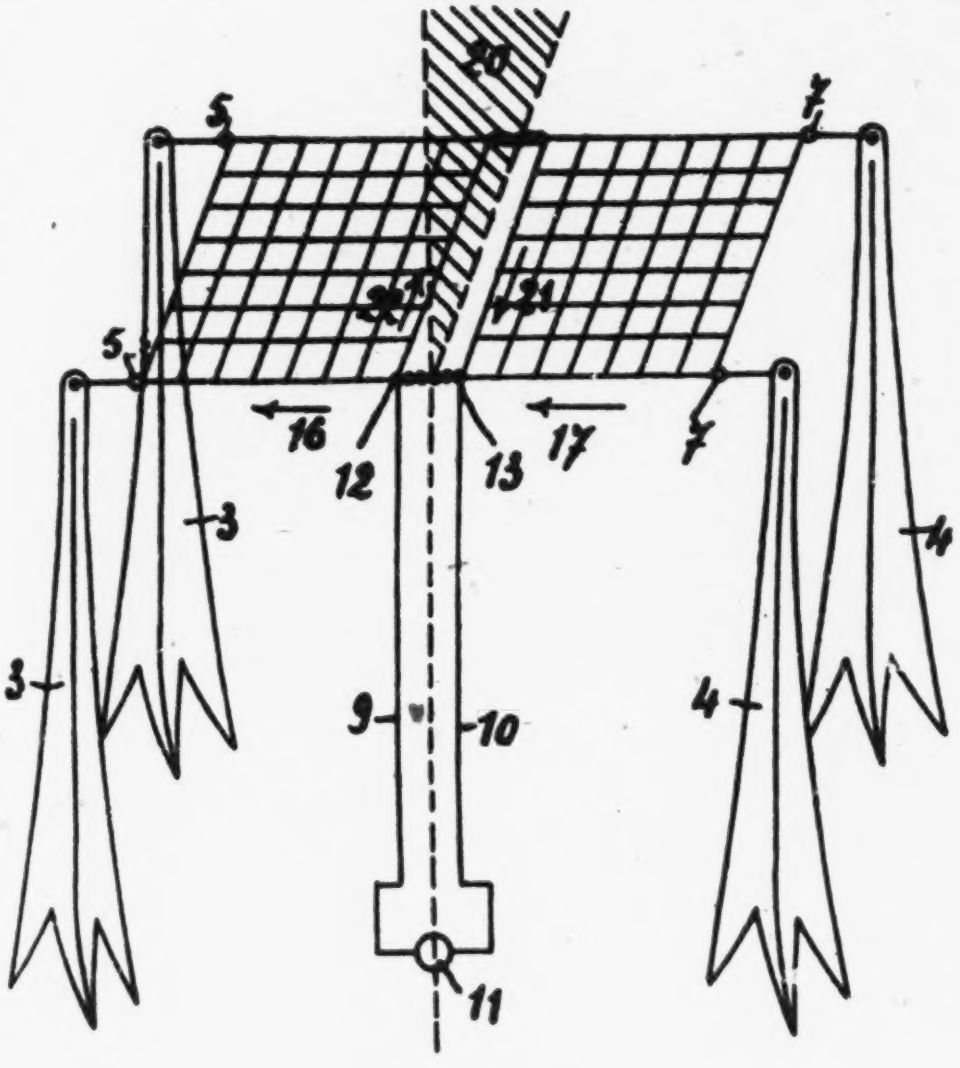
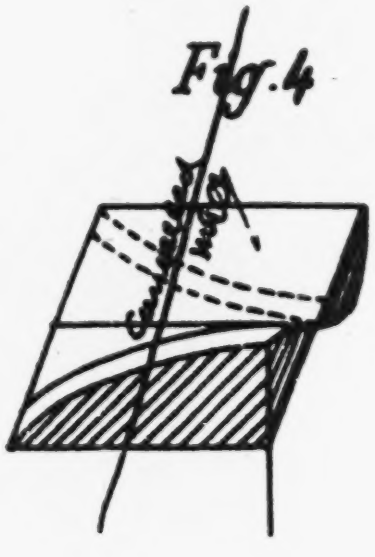


Fig.4

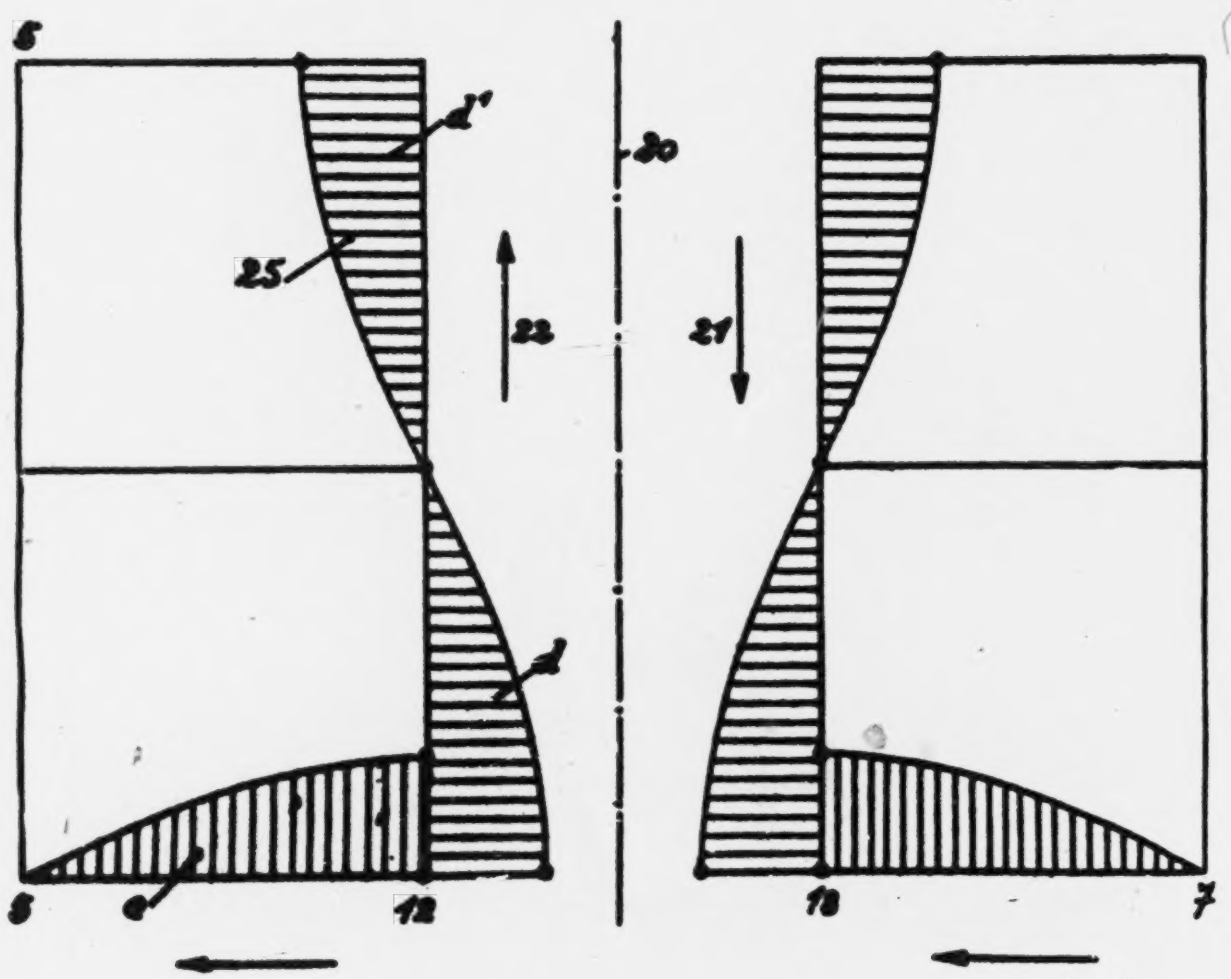


Charles & Read Ltd. Photo Litho

233,346 COMPLETE SPECIFICATION

SHEET 3

Fig. 4



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Fig 5



Fig 5ª

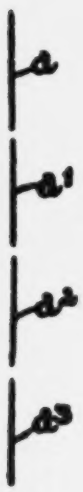
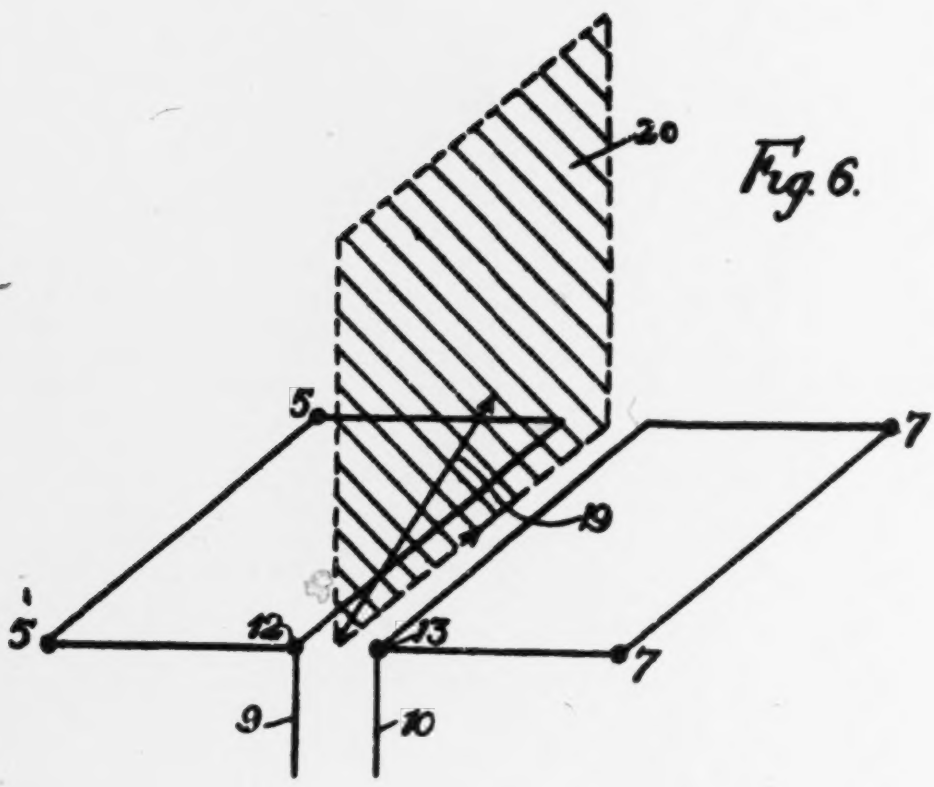


Fig 5ᵇ



Fig. 6.



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233.346 COMPLETE SPECIFICATION

5 SHEETS
SHEET 1

[This Drawing is a reproduction of the Original on a reduced scale]

Fig 7.

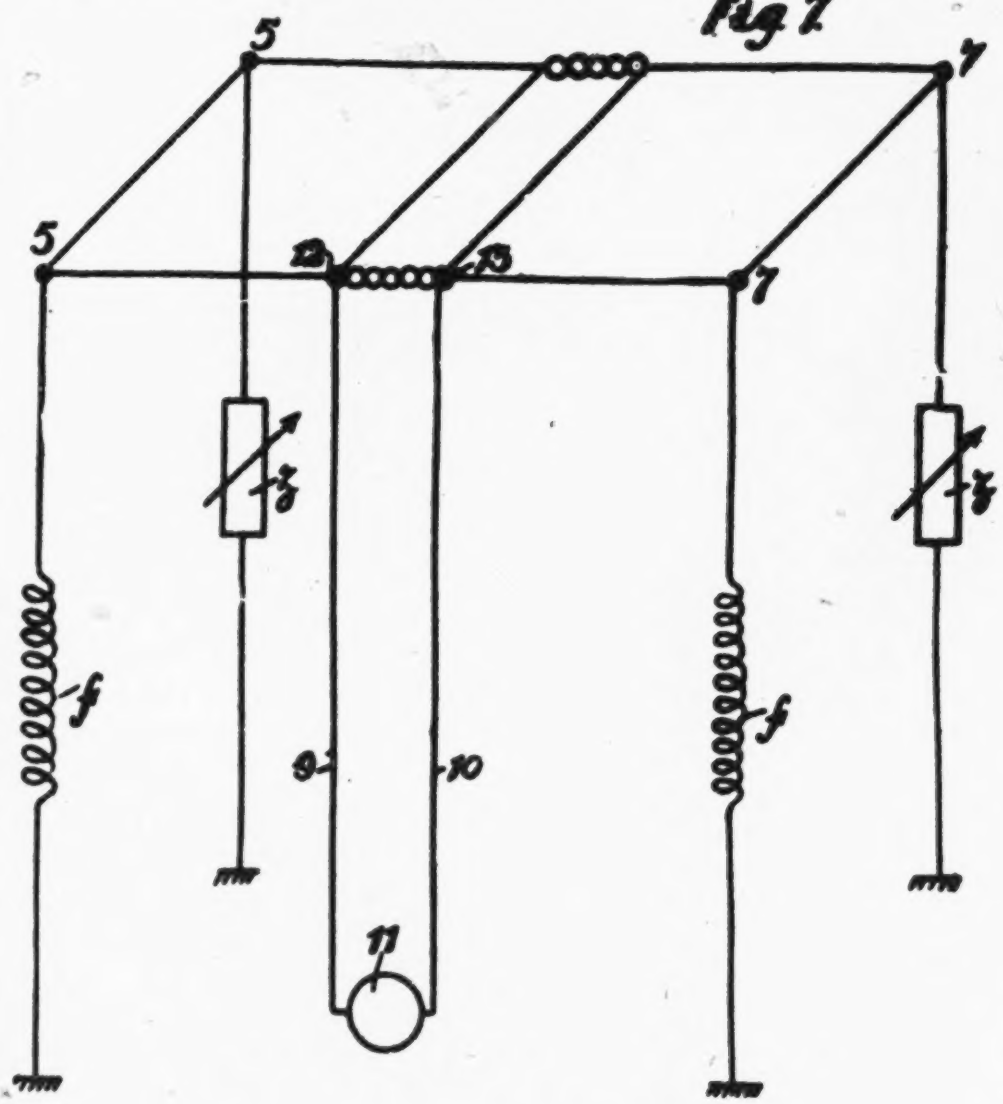
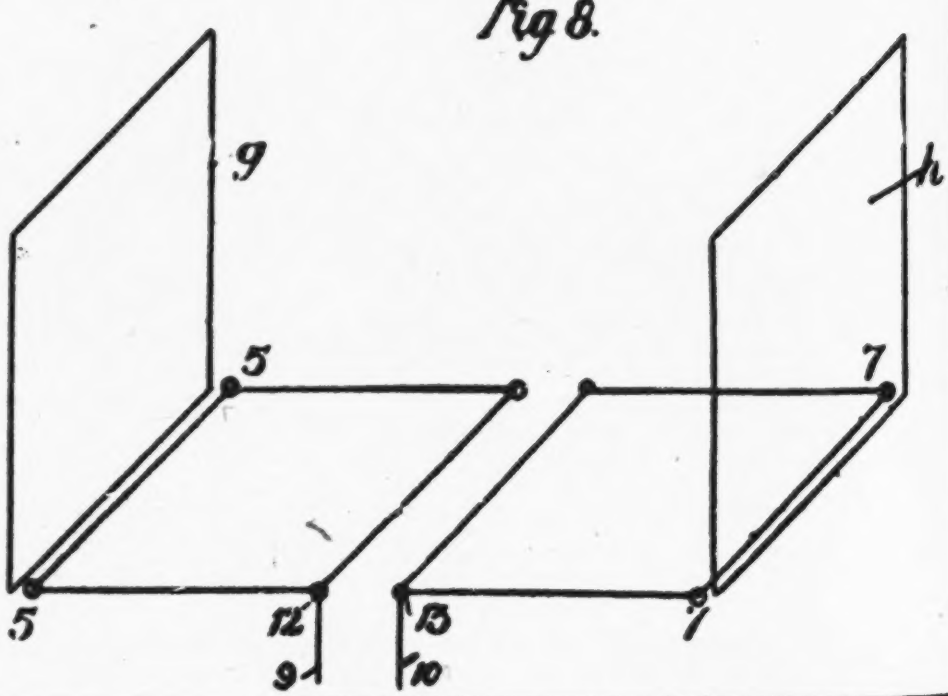


Fig 8.



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PLAINTIFF'S EXHIBIT No. 58

PATENT SPECIFICATION

Convention Date (France): April 28, 1925. **251,638**

Application Date (in United Kingdom): April 28, 1926. No. 11,211/26.

(Patent of Addition to No. 233,346: dated April 29, 1924.)

Complete Accepted: Oct. 28, 1927.

COMPLETE SPECIFICATION.

Improvements in or relating to Directive Aerials.

I, LUCIEN LEVY, of 66, rue de l'Universite, Paris, France, a citizen of the Republic of France, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to improvements in or modifications of directive aerials of the kind described and claimed in my Specification No. 233,346, in which the use of radiation with a horizontal electric vector was described.

It must first be observed that instead of the arrangements indicated in the above-cited specification, it is possible to contrive different modifications which may be advantageous in many cases, particularly when it is expedient to radiate energy in a given direction.

For instance, the wires 1 and 2 in the arrangement shown in Fig. 1 of the drawing annexed to the above-named specification, instead of being parallel to one and the same direction, may be placed so as to form an angle and may, for instance, be perpendicular to each other.

It is not necessary, however, to supply the different horizontal radiating elements with voltages of opposite phase and an improvement of my invention consists in supplying said elements with voltages which are out of phase relatively to each other by any amount, which may be constant or may vary with time. Further, two rotating high-frequency oscillators of different frequencies may be superimposed on one another.

Referring to the appended drawings, which illustrate as examples, various modes of application and of realisation of the improved arrangement; object of this invention:

Fig. 1 shows an aerial composed of two branches in the horizontal plane, but inclined to one another;

Fig. 2 shows a modified arrangement of the aerial;

Fig. 3 shows a further modification.

In Fig. 1 the radiators 1, 2 are situated in the same horizontal plane and at an angle less than 180°. In Fig. 2 the radiating planes are constituted by the wires 27, 23, 24 and 28, 25, 26.

These arrangements are characterised by horizontal radiating elements, through which high frequency currents pass at a sufficient height from the ground (greater than $\frac{1}{4}$ wave length), the two poles of the high frequency generator being respectively connected each to one or several radiating elements.

Fig. 3 shows an aerial with two horizontal radiating elements supplied with currents having any phase displacement.

In this arrangement, the points 29 and 30 of the element 34, 35 correspond to the points 5, 7 of the portion 1, 2 of the aerial; the points 12 and 13 of the radiating element 1, 2 are connected to the generator 11 and the points 31 and 32 of the radiating element 34, 35 are connected to the generator 33.

The generator 33 is 90° out of phase with regard to generator 11. These two generators have been shown as being separate for clearness, but usually they would not be separate and two circuits of a system comprising one or several thermionic tubes may actually be substituted.

When both radiating elements are perpendicular to each other and when the voltages at which they are supplied are

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of the same frequency and their phase is displaced by 90°, a horizontal electric field rotating at high frequency and with very peculiar radiating effects is produced. Said field is a circularly polarised field, its rotary frequency is equal to the frequency F of the currents passing through the radiators. The directive effect of the waves disappears.

When, however, currents of the same frequency F, but out of phase by less than 90°, pass through the radiators, an elliptically polarised field is produced.

Lastly, when two currents in mutually inclined conductors of equal amplitude and of frequencies F, and F_2, respectively, pass through each radiator—the two currents of the second radiator respectively differing in phase by ± 90° from the pair of currents in the first radiator, the superimposition of two rotating fields of different frequencies is produced. If one puts down $\omega 1 = 2\pi F_1$ and $\omega 2 = 2\pi F_2$, the components in a given horizontal direction, the whole field H is equal to $H. \sin \omega_1 t + H. \sin \omega_2 t$, consequently $H = 2 \sin \frac{\omega 1 + \omega 2}{2} t \cos \frac{\omega 1 - \omega 2}{2} t$, and everything takes place as if the field of frequency $\frac{\omega 1 + \omega 2}{2}$ rotated at a speed $\frac{\omega 1 - \omega 2}{2}$ t in a horizontal plane. The result is the same for the radiated field, and a field rotating at the speed of $\frac{\omega 1 - \omega 2}{2}$, which is slower than the emitting pulsation $2\pi F$. is produced in any point in space. The fields may be rotated at a speed of approximately 1000 or even 10,000 turns per second.

As will be seen, the system which has just been described allows of producing at the receiving station a horizontal oscillating electric field whose plane of polarisation rotates at a speed comprised between zero and $2\pi F$.

This result is of great importance as it allows of a real synchronising between the sending and the receiving stations and an absolutely certain suppression of parasites which do not appear in any way in such a form of rotary fields.

The first essays made with horizontal waves give considerable ranges, even by day, and upon wave lengths of the order of 80 m. with the disappearance of the fading effect. Radiation takes place apparently not only in the expected direction but also perpendicularly, and that may be explained by the effects of circular polarisation referred to above.

It must be noted that the generators feeding the horizontal aerials are supposed to be placed on the ground and to be connected to the radiating part of the aerial by a double wire line, this arrangement being evidently necessary when it is desirable to maintain the generator upon the ground, the lowest height of the aerial above the ground being given. If, however, the generator may be supported on a level with the aerial, the feeding line is omitted.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A directive aerial as claimed in Specification No. 233,346, comprising two radiating elements situated in a horizontal plane, at a height above the ground, and connected to a generator which can be either level with the aerial or located upon the ground, and connected to the aerial by means of a double wire line, characterised in that the two said radiating elements are rectilinear and mutually inclined.

2. A directive aerial as claimed in Specification No. 233,346, further characterised in that the radiating elements are supplied with voltages out of phase relatively to one another, for instance, by 90°.

3. A directive aerial as claimed in the preceding claims, adapted to generate radiation polarised in a rotating plane.

4. The directive aerials, substantially as described and as illustrated in the accompanying drawings.

5. The method of electromagnetic transmission at a distance, substantially as described and illustrated in the accompanying drawings.

Dated this 27th day of April, 1926.

MEWBURN, ELLIS & Co.,
70—72, Chancery Lane, London, W.C. 2.
Chartered Patent Agents.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1927.

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251,638 COMPLETE SPECIFICATION

SHEET 1

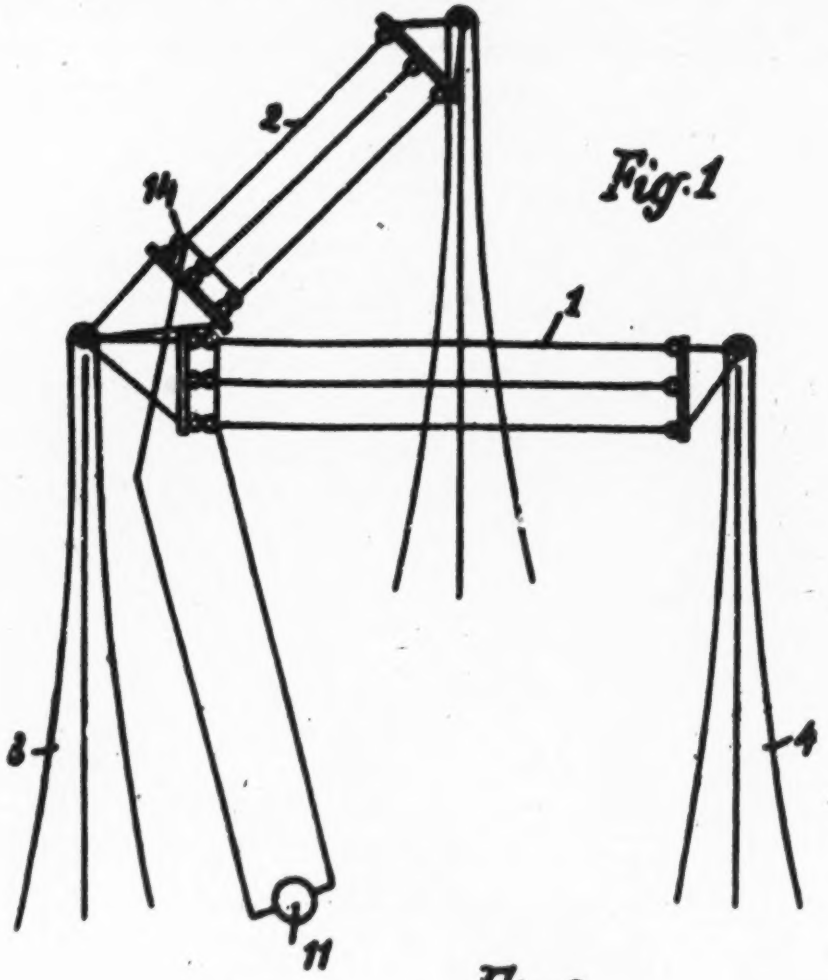
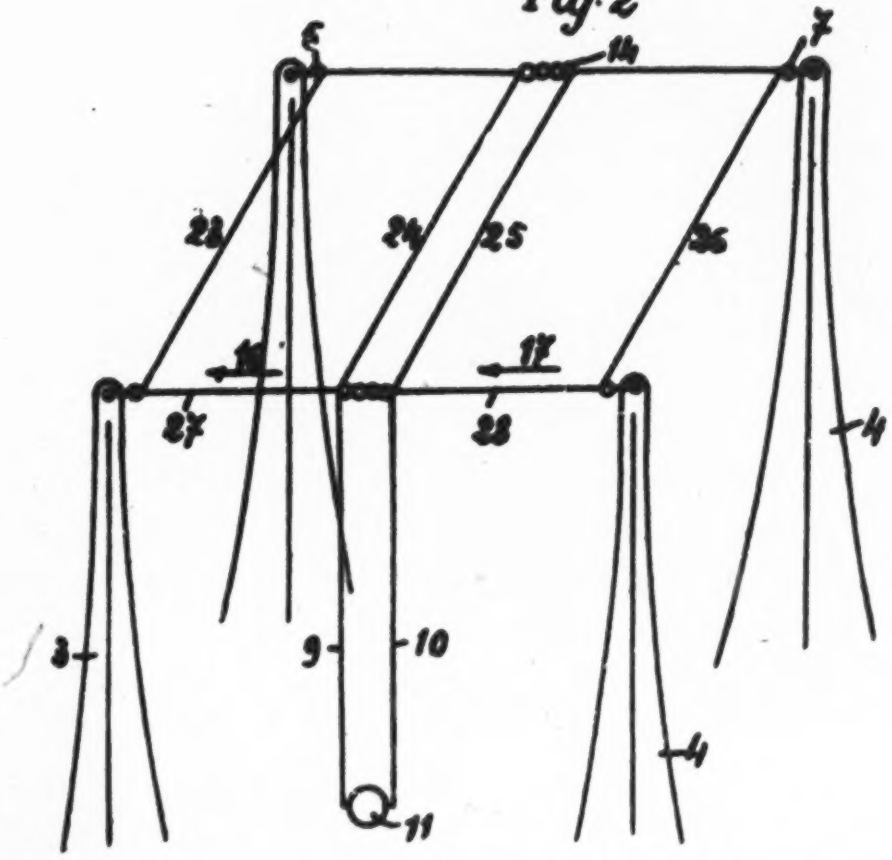


Fig. 1

Fig. 2

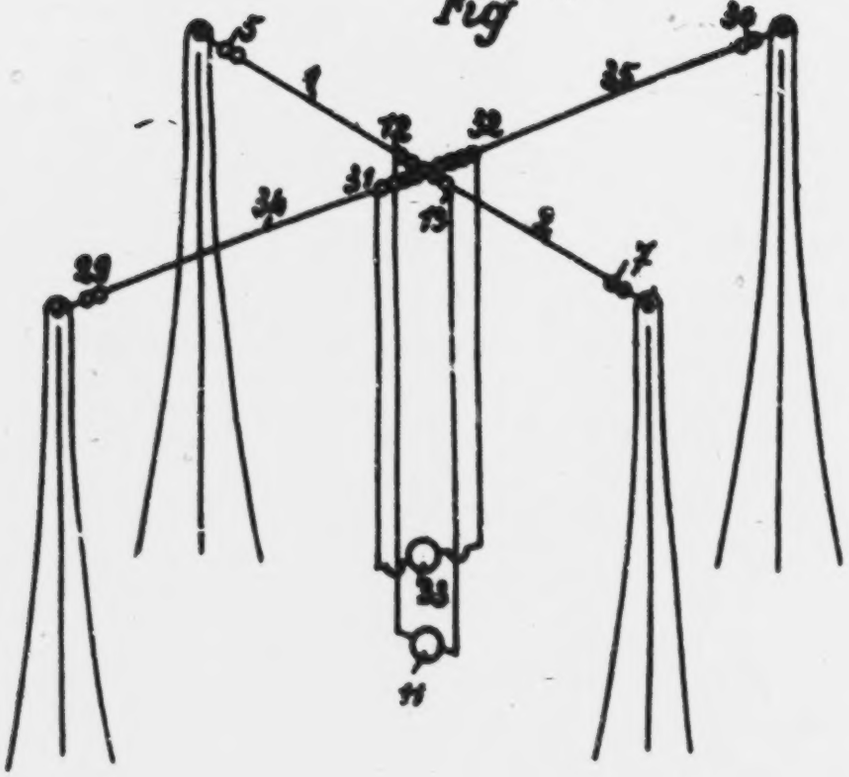


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251638

Fig 3



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DEFENDANT'S EXHIBIT A

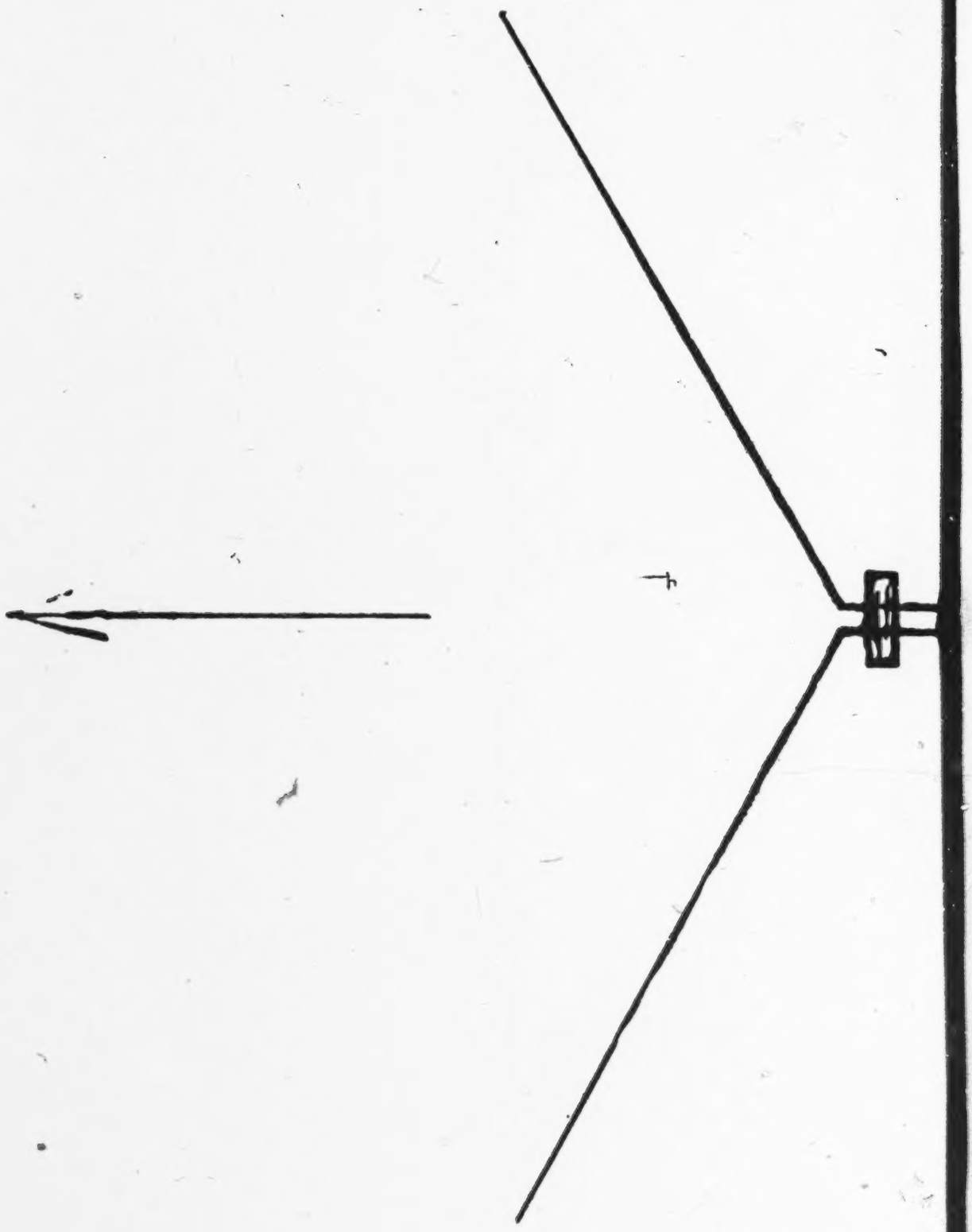




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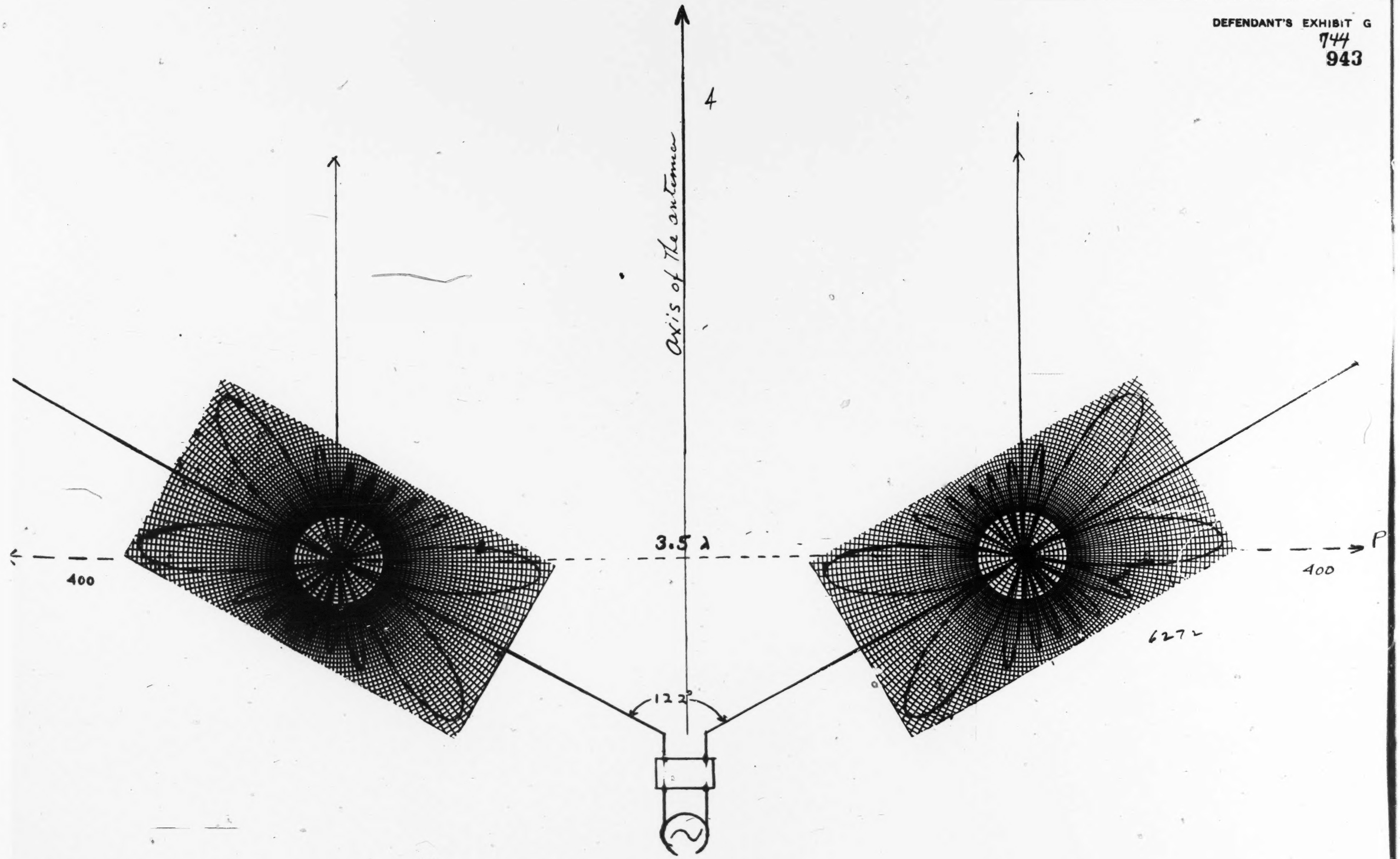
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DEFENDANT'S EXHIBIT F



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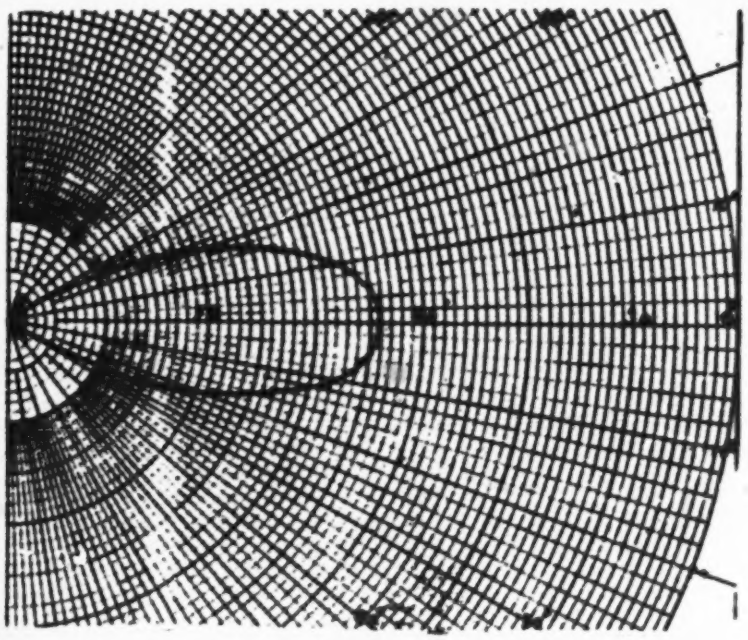


DEFENDANT'S EXHIBIT 944

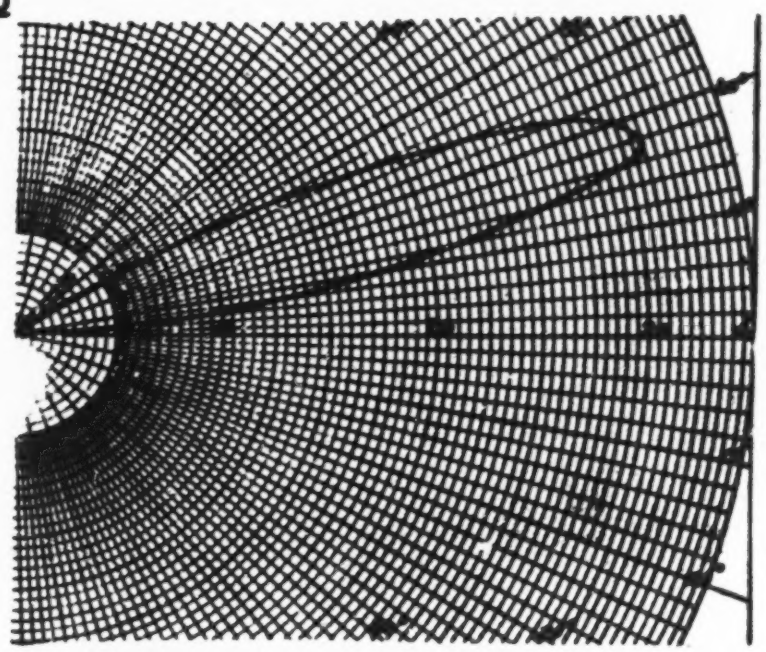
RADIATION PATTERN OF DEFENDANT'S ANTENNA NO 8

WHAT IT WOULD BE IN A DIRECTION ALONG THE BISECTOR OF THE ANGLE OF THE CONDUCTORS

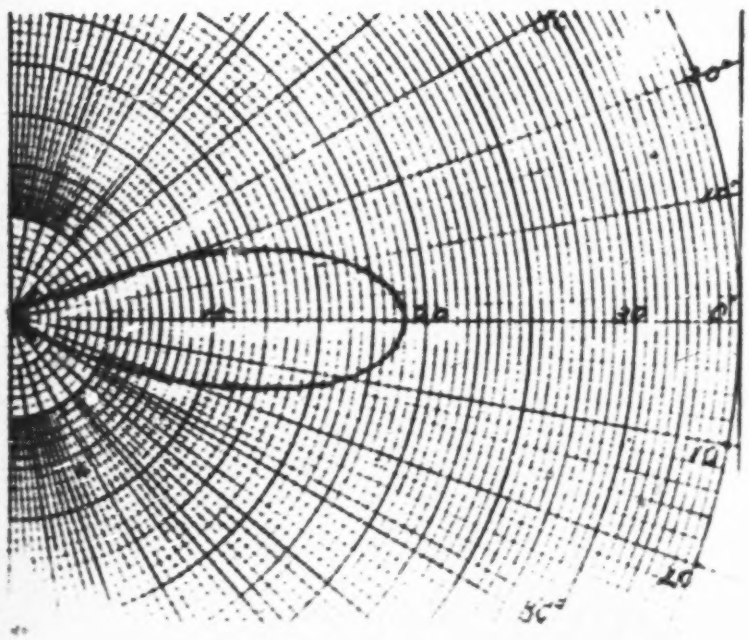
Angle of V 45°

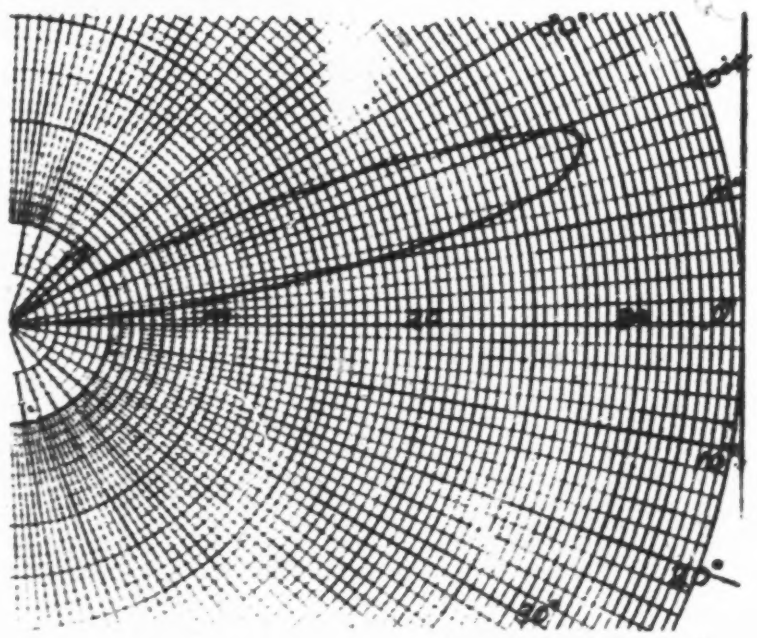


WHAT IT ACTUALLY IS



WHAT THE CORRESPONDING PATTERNS WOULD BE IF THE ANGLE OF V WERE 50°





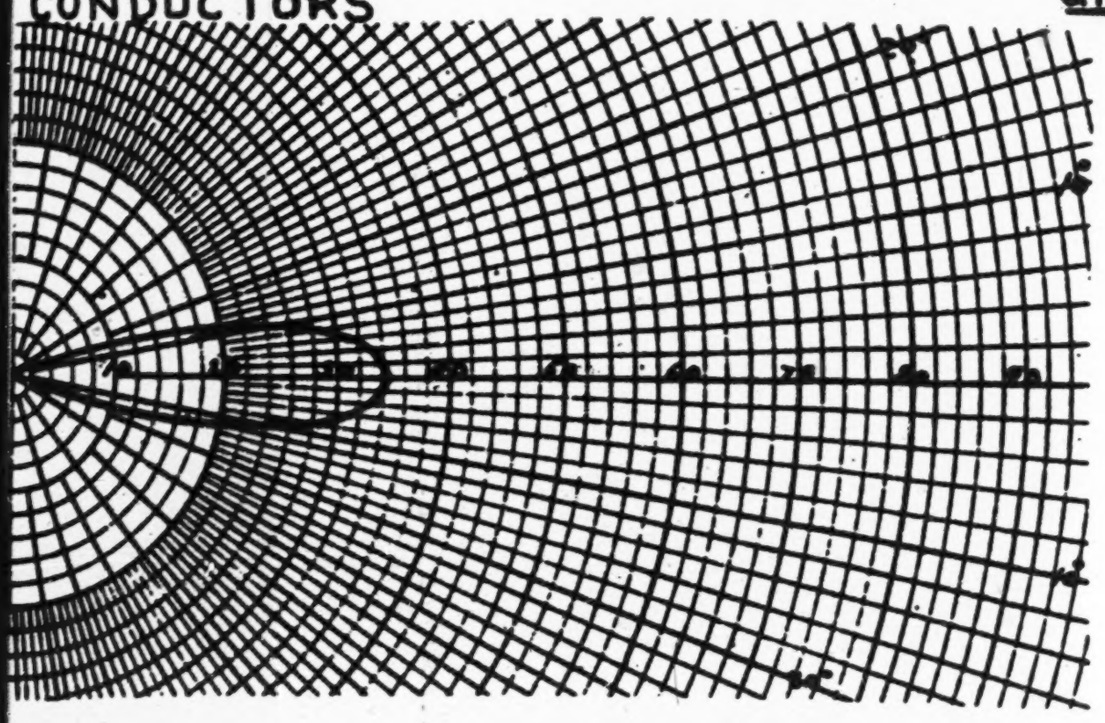
DEFENDANT'S EXHIBIT T

RADIATION PATTERN OF DEFENDANT'S ANTENNA NO. 2

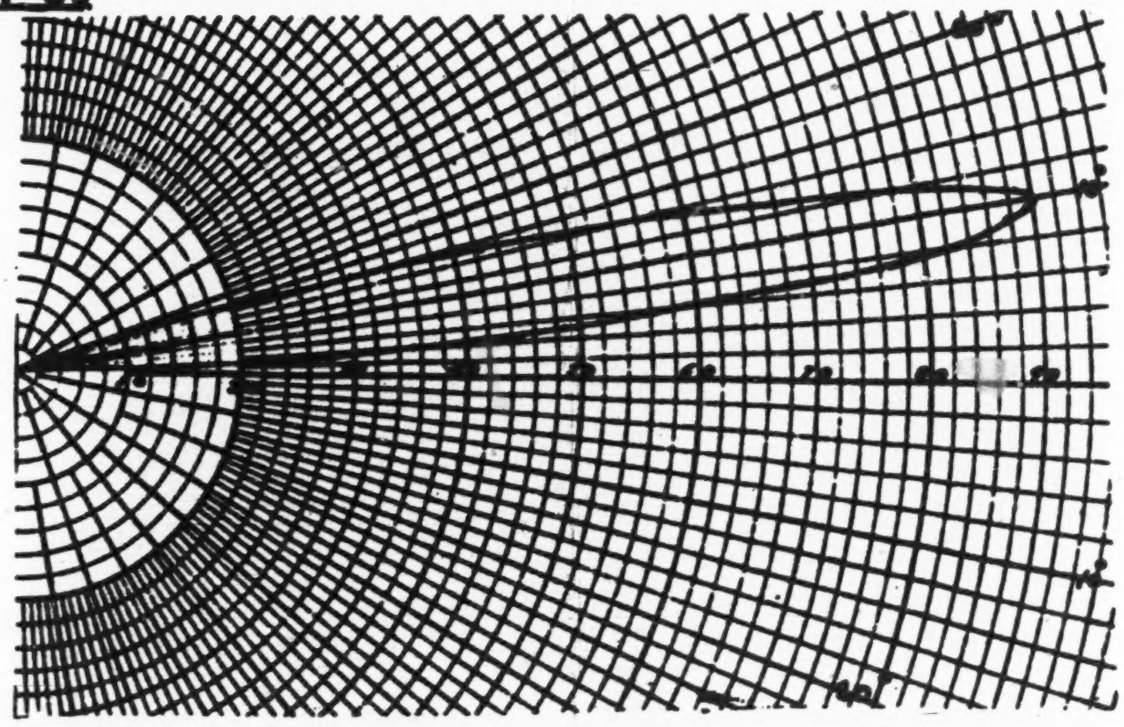
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WHAT IT WOULD BE IN A DIRECTION ALONG THE BISECTOR OF THE ANGLE OF THE CONDUCTORS

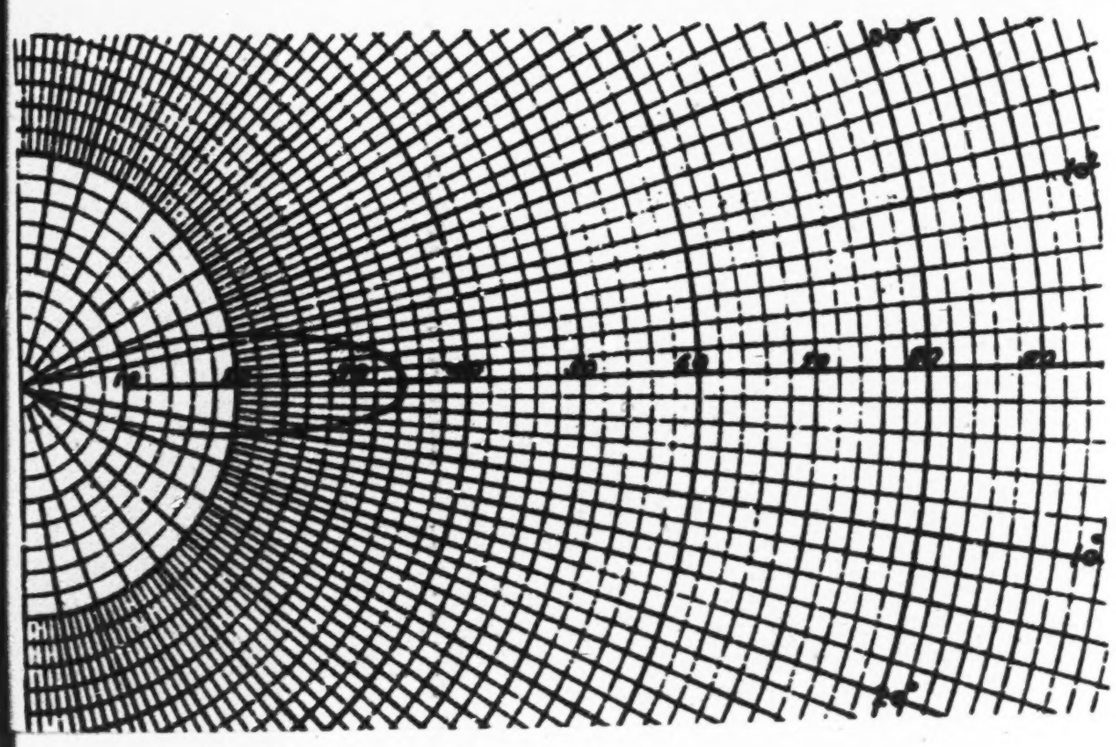
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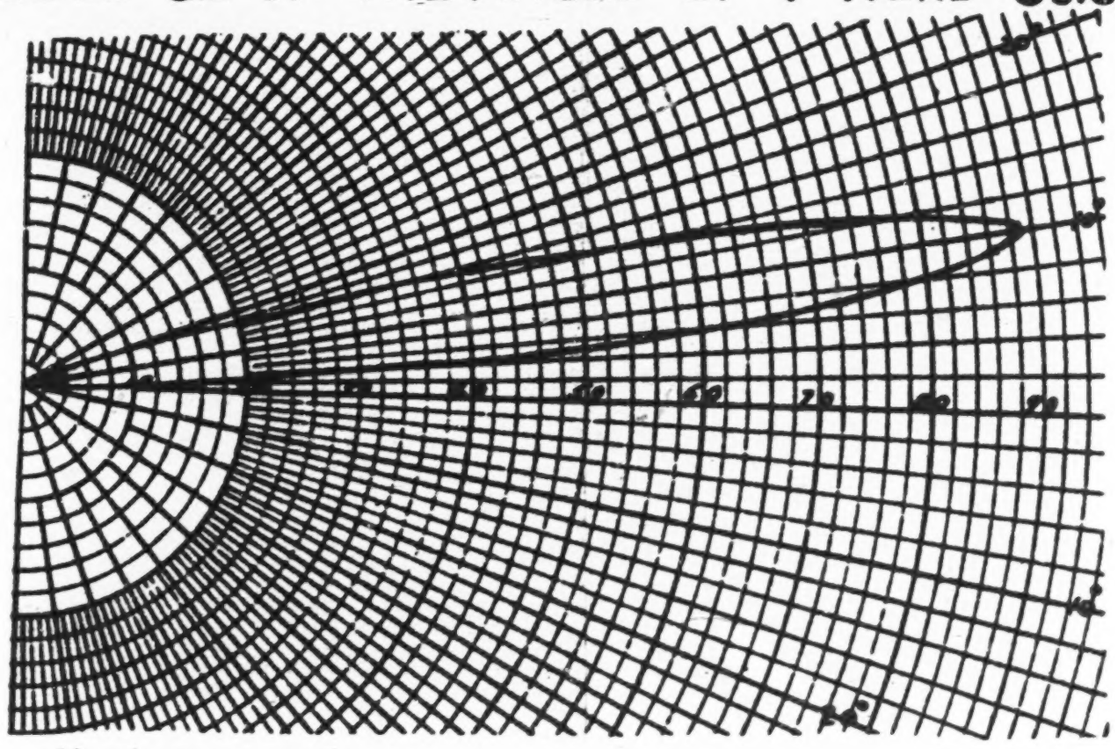


WHAT IT ACTUALLY IS



WHAT THE CORRESPONDING PATTERNS WOULD BE IF THE ANGLE OF V WERE 35.6°





[fols. 946-959] DEFENDANT'S EXHIBIT U

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Jan. 7, 1936. P. S. CARTER 2,027,020

DIRECTIONAL ANTENNA

Filed Sept. 15, 1932 4 Sheets-Sheet 1

Fig. 1

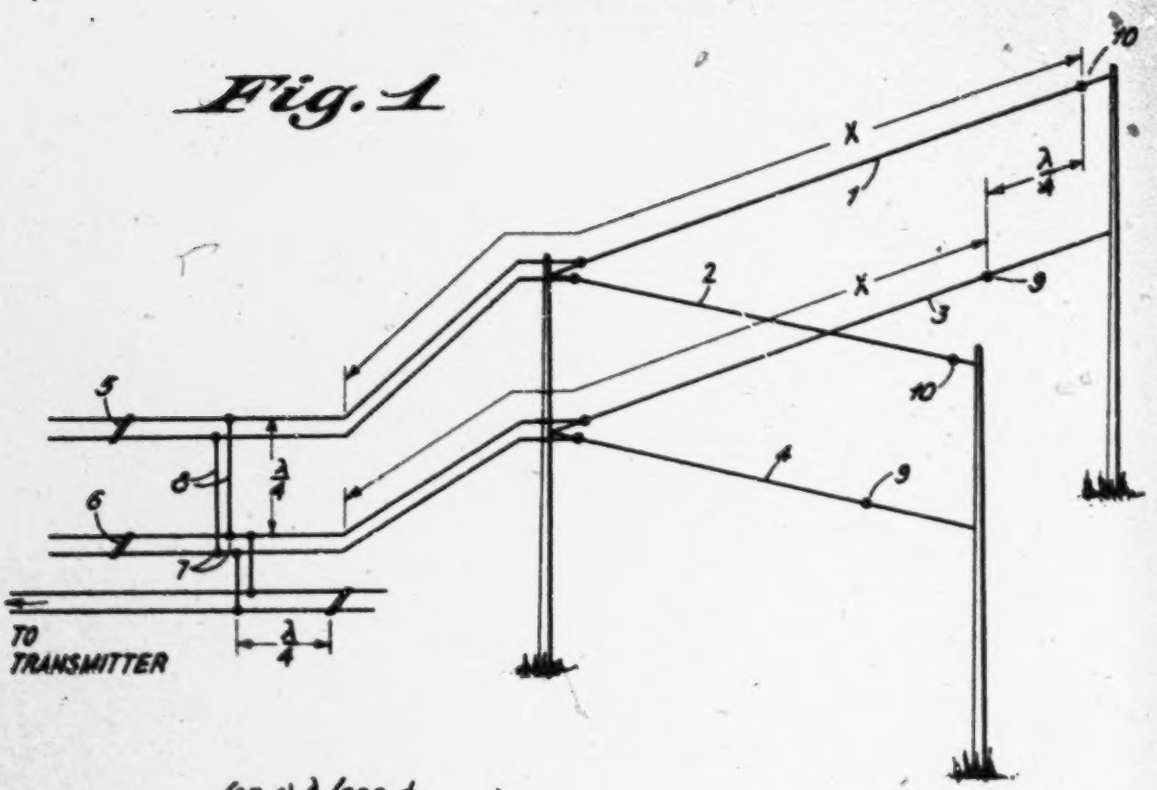


Fig. 2a

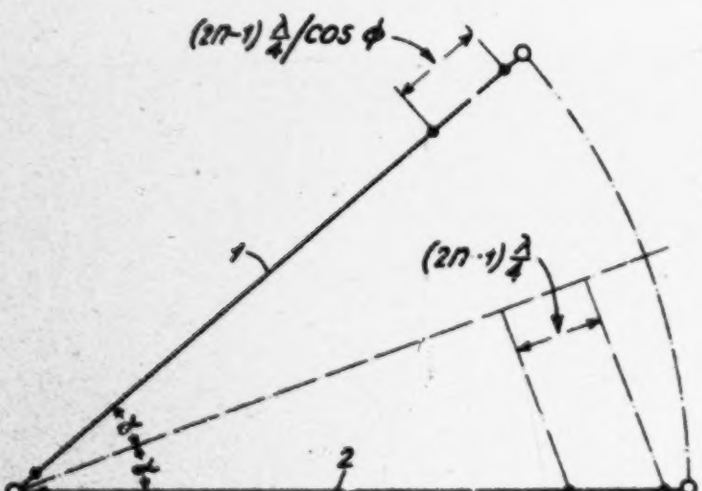
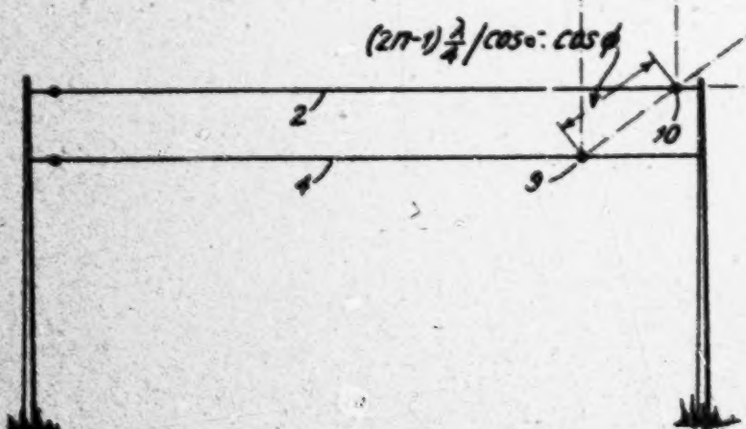


Fig. 2b



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Jan. 7, 1936. P. S. CARTER 2,027,020

DIRECTIONAL ANTENNA

Filed Sept. 15, 1932 4 Sheets-Sheet 2

Fig. 3

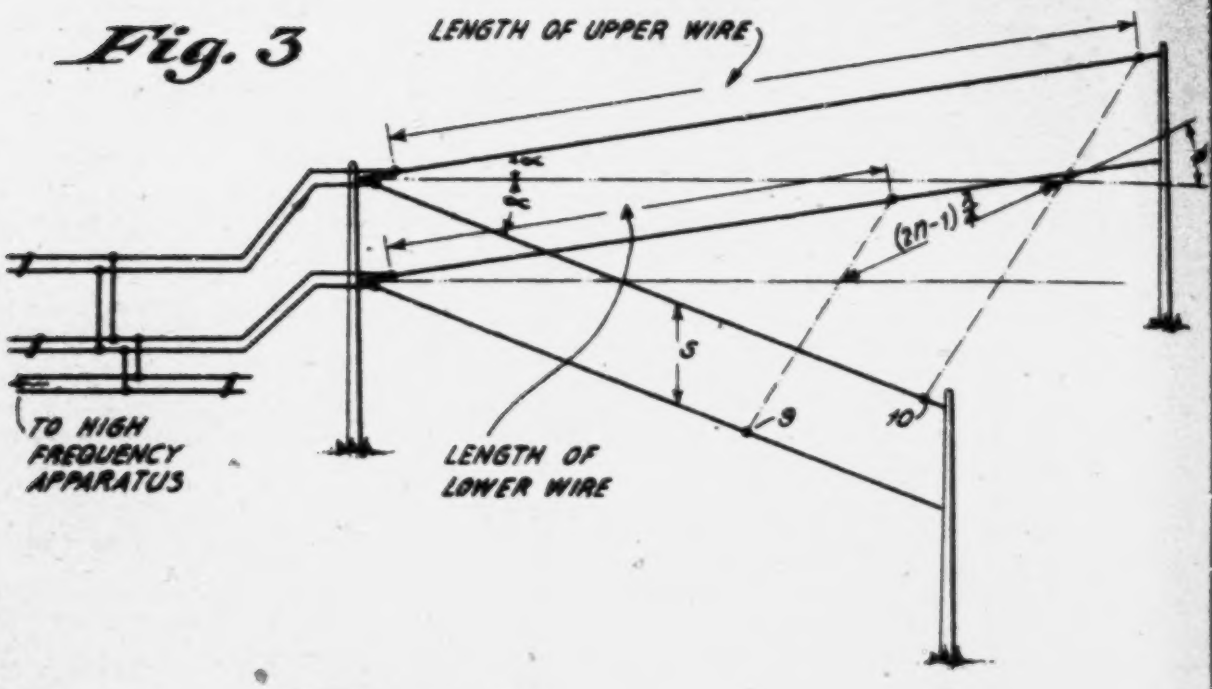
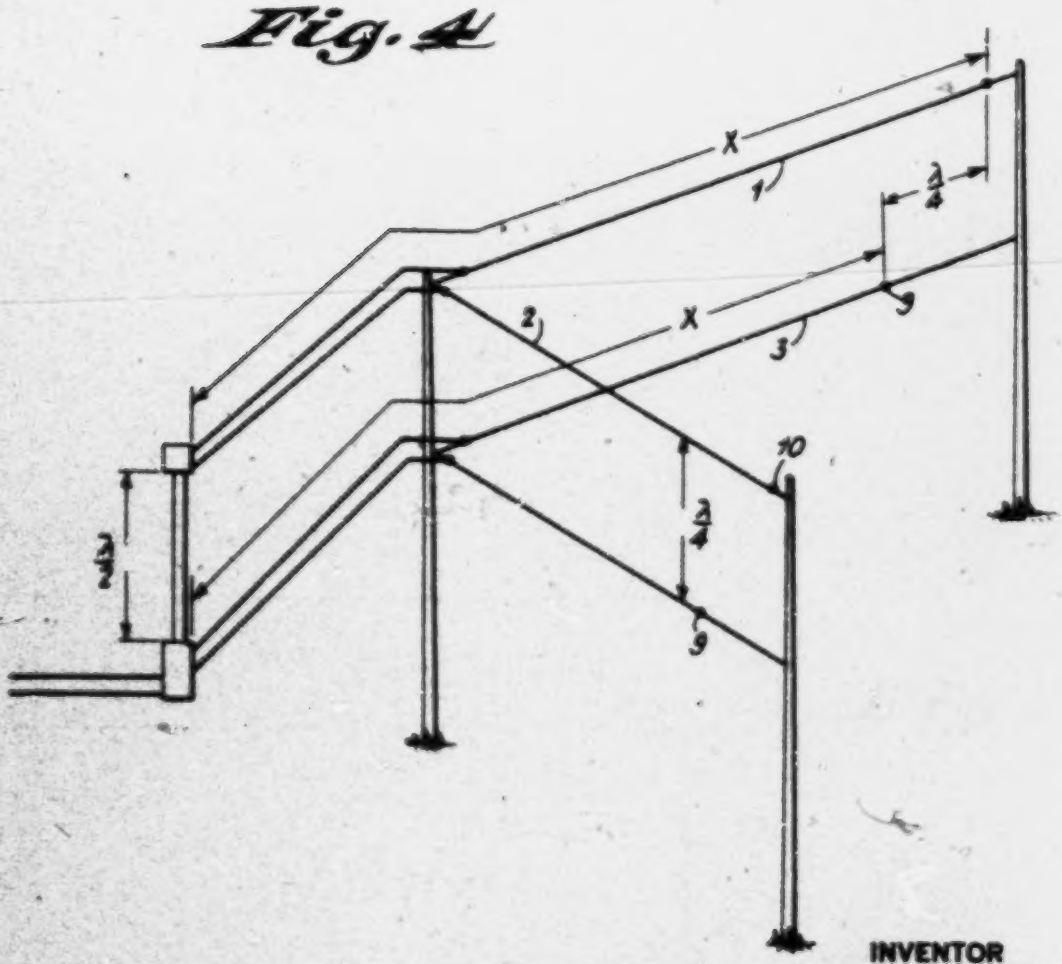


Fig. 4



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Jan. 7, 1936. P. S. CARTER 2,027,020

DIRECTIONAL ANTENNA

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Fig. 5

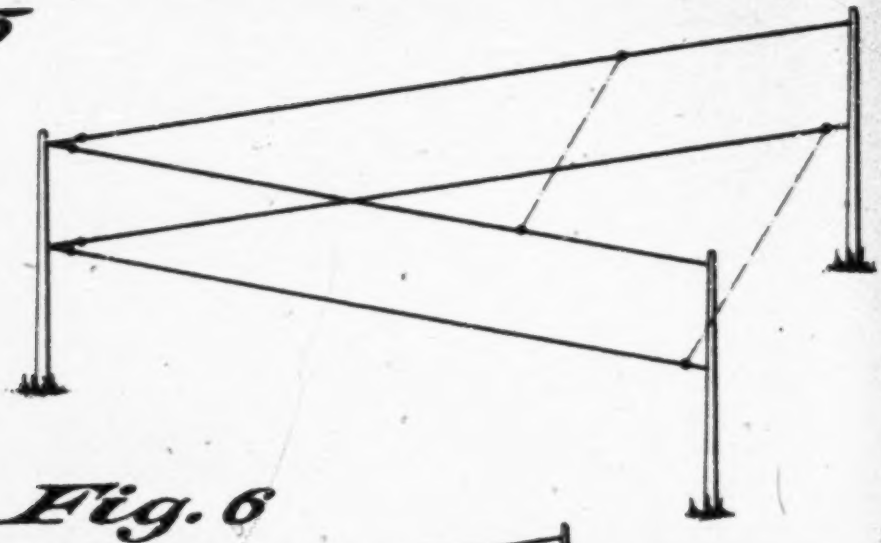


Fig. 6

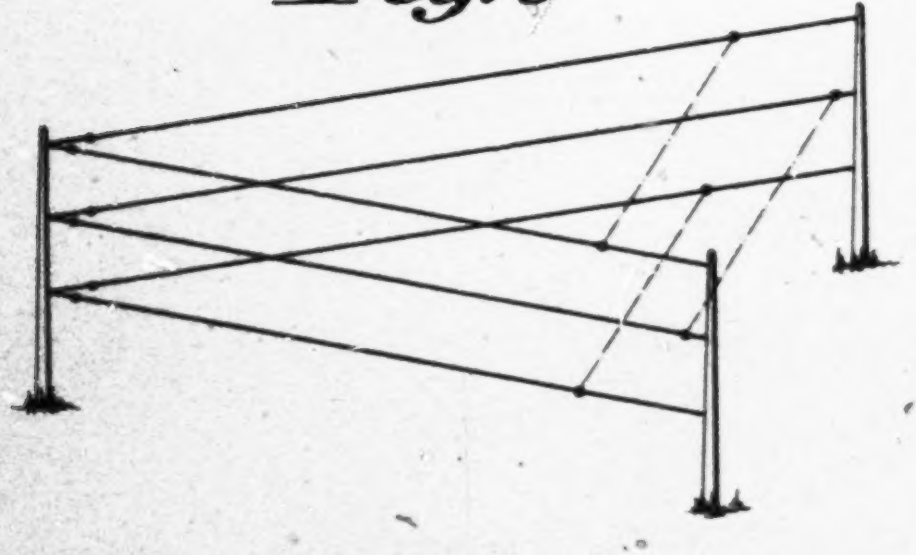
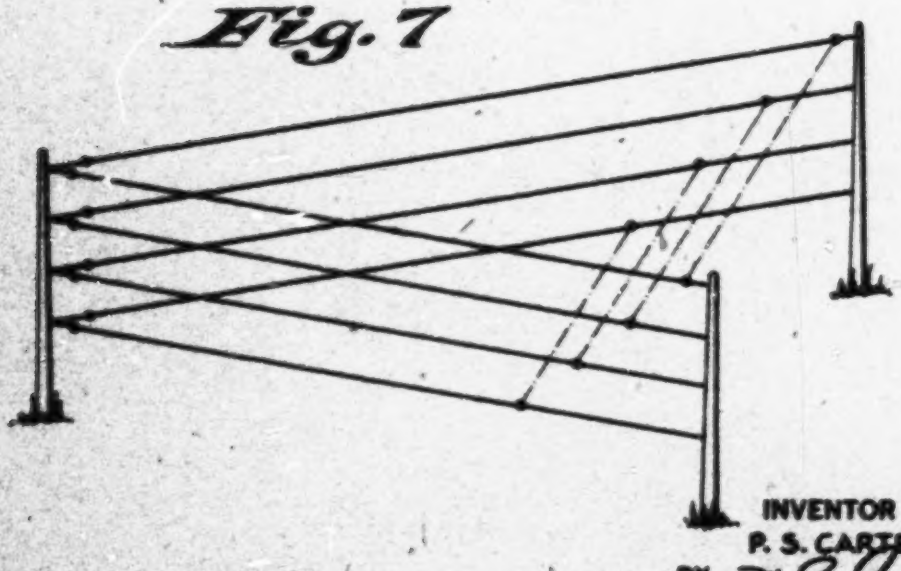


Fig. 7



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754

Jan. 7, 1936. P. S. CARTER 2,027,020

DIRECTIONAL ANTENNA

Filed Sept. 15, 1932 4 Sheets-Sheet 4

Fig. 8

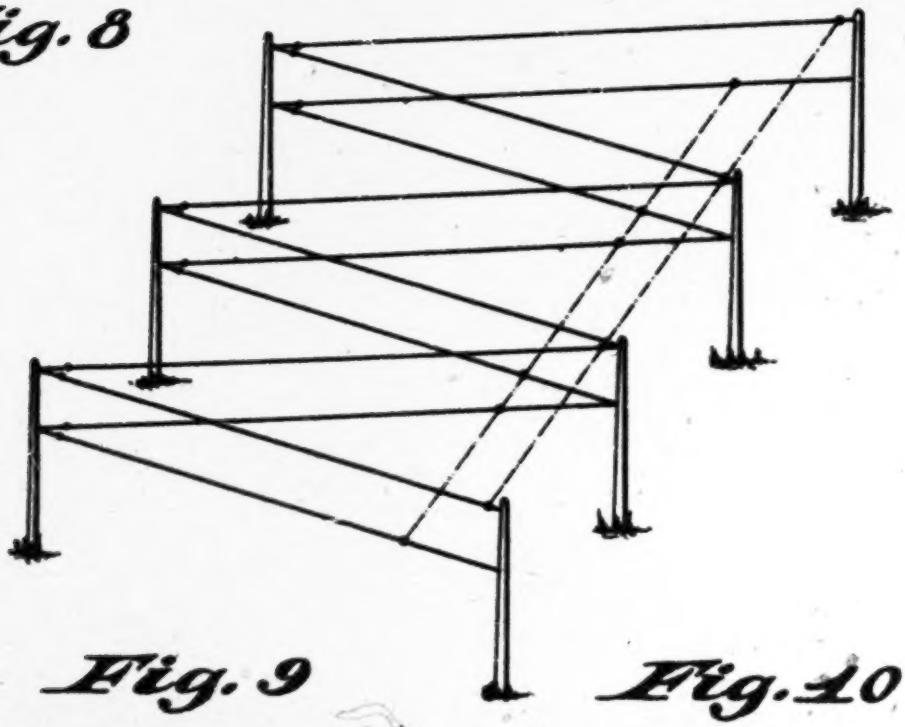


Fig. 9

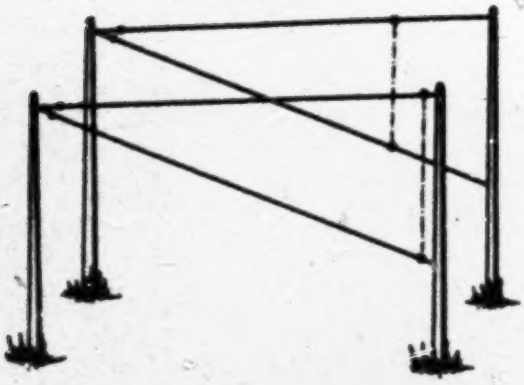


Fig. 10

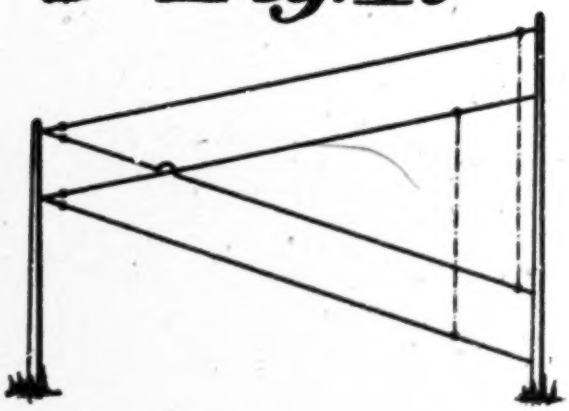
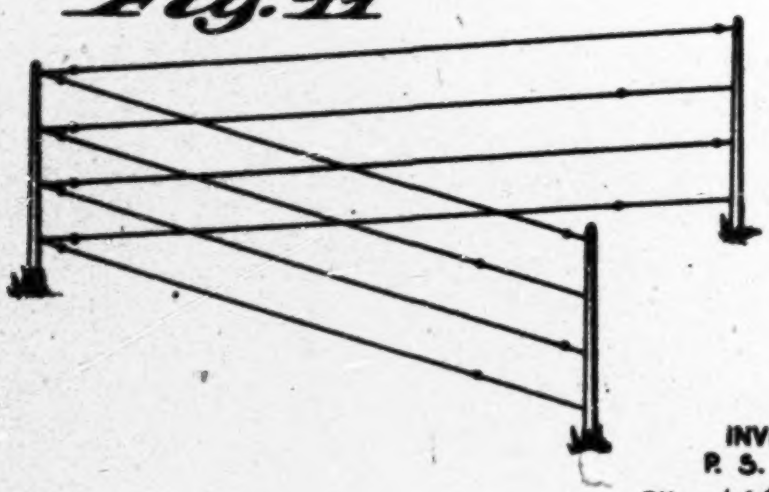


Fig. 11



INVENTOR
P. S. CARTER
BY H. B. Grover
ATTORNEY

Patented Jan. 7, 1936

2,027,020

UNITED STATES PATENT OFFICE

2,027,020

DIRECTIONAL ANTENNA

Philip S. Carter, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application September 15, 1932, Serial No. 633,229

28 Claims. (Cl. 250—11)

This invention relates to antenna systems and more particularly to directive antenna systems.

In my United States Patent No. 1,974,387, granted September 18, 1934, there is described a V type antenna arrangement which is adapted to radiate energy directively. This arrangement comprises a pair of linear conductors which are long relative to the length of the communication wave and disposed at an angle in such a manner that when energized radiation occurs principally along the bisector of the angle. Such a V type antenna, it has been found, has a bi-directional characteristic radiating equally well in two directions—namely, toward the diverging ends of the conductors, and toward the converging ends of the conductors.

Heretofore, in order to obtain a unidirectional characteristic it has been the practice to place a similar parallel pair of wires arranged in the same V formation mentioned, an odd number of quarter wave lengths away from the antenna proper in a direction along the bisector of the angle formed by the wires. This second pair of wires is then left unenergized, or energized in proper quarter phase relation such that for one direction radiation cancellation occurs whereas in the other direction there is a strengthening of the propagated electromagnetic waves.

A disadvantage inherent in the system above referred to is the necessity for providing separate supporting structures for the second set of V type conductors in order to obtain the unidirectional antenna effect. The present invention overcomes this disadvantage and enables uni-directional radiation of electromagnetic energy without the necessity for the second set of supporting structures. Consequently, there is obtained, in accordance with the present invention, a system which is simplified in character and less expensive to construct and to maintain. As an illustration: Heretofore a single section V type uni-directional antenna system has required six supporting structures; the present invention has reduced this number to only four.

Essentially, the present invention comprises a uni-directional radiating system wherein two V formations of linear conductors, which are long relative to the length of the communication wave, are placed one above the other and energized in such a manner that the currents in the two V's are in phase quadrature relation with respect to each other. The radiated wave leaving the lower wires is arranged to be in leading phase with respect to that leaving the upper wire by a phase angle equivalent to the spacing along the line of the desired maximum radiation, thus adding perfectly to the radiated wave leaving the upper wire. In the reverse direction, the two waves are arranged to cancel out because of a desired time and space relation. In order to obtain correct space relation and reflector action, the wires of the lower V are shortened by a desired amount.

The invention is described more in detail in the following description, which is accompanied by drawings, wherein

Figure 1 illustrates a V type antenna system embodying the principles of the present invention; and

Figure 2a illustrates, in part, a plan view of the system of Figure 1, and Figure 2b, in part, a side view of the system of Figure 1, both parts being favorably arranged for a discussion of the principles involved in the present invention.

Figure 3 illustrates an arrangement differing from that of Figure 1 in that this arrangement causes the radiation from the upper and lower V's to add best at an angle of θ degrees to the horizon.

Figure 4 shows a system in accordance with the present invention wherein the spacing between the upper and lower wires is made one quarter wave length in order to obtain simplicity in phasing.

Figure 5 shows an arrangement similar to that of Figures 1 and 2 except that the upper wires are made shorter than the lower.

Figure 6 illustrates a system of three V's, one above the other, in which the lower and upper units are made shorter and fed in even quadrature phase with respect to the center unit.

Figure 7 illustrates a system of four V's, one above the other, in which each successive V is shorter than the one above.

Figure 8 illustrates a broadside system in accordance with the present invention, utilizing three sections.

Figure 9 illustrates an arrangement in which both of the V's lie in vertical planes and in which one of the two V's is made shorter than the other.

Figure 10 shows an arrangement wherein two V's lie in the same vertical plane and are carried by the same structures.

Figure 11 shows an arrangement of four V's lying in horizontal planes, one above the other, and made alternately long and short, the shorter V's being fed in quarter phase relation with respect to the longer V's.

Referring to Figure 1, there is shown an antenna system adapted for uni-directional radiation of electromagnetic energy comprising an upper pair of conductors 1 and 2, which are made long relative to the length of the communication wave and disposed in a horizontal plane in V formation at an angle in such manner that radiation occurs principally along the bisector of the angle. This angle depends upon the length of the conductors and the wave length in a manner which is fully described in my United States Patent

No. 1,974,387 mentioned above. Immediately below wires 1 and 2, spaced therefrom a convenient distance and mounted on the same supporting structures, are located another pair of conductors 3 and 4, also in V formation, each of the latter being respectively parallel to conductors 1 and 2.

In order to obtain the desired directive action, the lower V, comprising wires 3 and 4, is arranged so that the currents therein are in phase quadrature with respect to the currents in the upper V. One method of accomplishing this, while at the same time enabling the matching of the impedances of the transmission lines, is shown in Figure 1 wherein adjustable connection 5 enables the tuning of upper V wires 1 and 2 and adjustable strip 6 enables the tuning of the lower V wires 3 and 4. Connections 7, 7 are also arranged to be adjustable for matching the impedances of the quarter wave length jumpers 8, 8. When properly adjusted, the correct quarter wave phase relation may thus be obtained. For proper operation, the lengths of the wires extending from the ends of the conductors to corresponding positions on the upper and lower feeder pairs of the impedance matching structure, which are indicated by x, x in the drawings, should be made equal, although it will be understood that the absolute lengths are immaterial.

So far, the effects of ground upon the resulting radiation have not been mentioned. In both theory and practice it has been found that the reflections from ground are such as to always result in zero radiation horizontally at the usual communication distances from any short wave antenna. It has also been found that radiation at angles in the neighborhood of 10° to the horizon is most effective at a distance receiver. By placing a V wire radiator at a height of one wave length above the average dry ground, maximum radiation takes place at about 10½° to the horizontal. Therefore the antenna arrangement usually preferred is one in which the radiation from the lower and upper conductors adds perfectly at an angle of about 10° to the horizon and in which the mean height is of the order of one wave length.

To eliminate difficulties in adjustment caused by large mutual impedance between units, it is preferable to have the spacing between the upper and lower conductors at least one quarter wave length.

Dimensions which might be used in a typical design are as follows:

Length of upper wire=8 wave lengths

Angle of maximum radiation=10° to the horizon

Effective spacing=1¾ wave lengths along the line inclined at 10° to the horizon in the bisecting plane.

Half angle of V=α=18.5°

Lower conductors 3 and 4 are arranged to be shorter than upper conductors 1 and 2 by an amount sufficient to result in the correct space relation for reflector action. The distance between the end of the wire on the lower V and the end of the corresponding upper wire on the upper V is made an amount such that when projected upon the line of desired maximum radiation the projection is an odd number of quarter waves. There are several ways by which this relation may be accomplished, depending upon the particular condition it is desired to fulfill.

If it is desired that maximum addition of the radiation from the two V units take place horizontally then the following equation must be satisfied

$$X \cos \alpha = (2N-1)\frac{\lambda}{4}$$

wherein X is the stagger or horizontal distance between insulators 9—10, α the half angle of the V wires, N any integral number, and λ the wave length. Such an arrangement is illustrated in Figure 2.

If it is desired that maximum addition of radiation take place at an angle θ to the horizon, and a definite spacing S between wires 2 and 4 has been given, then the relation

$$X \cos \theta \cos \alpha + S \sin \theta = (2N-1)\lambda/4$$

must be satisfied.

If a definite angle ϕ for the line d between insulators 9—10 with respect to the horizon be assigned, and it is desired that best addition take place at the angle θ, the length of the line d may then be determined from the relation

$$d \cos \theta \cos \delta \sin \phi \cos \alpha + d \sin \phi = (2N-1)\lambda/4$$

In Figure 3 is shown a system so designed that the projection of the line d between the insulators of the upper and lower wires upon the plane bisecting the V wires coincides with the line of desired maximum addition of radiation. This is a convenient arrangement but not necessarily better than others satisfying the relations set forth.

The projection of the line d between insulators 9 and 10 in Figure 1 upon the bisecting plane should coincide with the line of maximum radiation (10° to the horizon according to Figure 3). With the foregoing conditions the following relations obtain:

$$1.75\lambda \cos 10° = d \cos \phi \cos 18.5°$$
$$1.75\lambda \cos 10° = d \sin \phi$$

from which $\tan \phi = \tan 10° \cos 18.5°$ and $\phi = 9.5°$

$$d = 1.\tfrac{3}{4} \frac{\sin 10°}{\sin 9.5°} = 1.842\lambda$$

$$\text{spacing} = S = d \sin \phi = 0.304\lambda$$

Another arrangement which has the advantage of making possible correct phasing adjustment on the antenna structure itself is shown in Figure 4. In this arrangement the vertical spacing is made

$$(2N-1)\frac{\lambda}{4}$$

with straight connections when N is odd and reversal of connections when N is even. A typical design might be:

Length of upper radiators=8 wave lengths

Angle of maximum radiation=about 10° to the horizon

Vertical spacing=¼ wave length

Effective spacing along the line of maximum radiation at 10° to the horizon=¼ wave length

Half angle of V=17.5°

$$X = \frac{\frac{\lambda}{4} - \frac{\lambda}{4} \sin 10°}{\cos 10° \cos 17.5°} = 0.88 \frac{\lambda}{4} = .22\lambda$$

Length of lower wires=$8\lambda - \chi = 7.78\lambda$

The direction of maximum radiation may be reversed by making the current in the lower V lag that in the upper, assuming, of course, that the lower V wires are the shorter.

For convenience in describing this invention

it has been assumed that the shorter wires are placed below the longer. If desired, the shorter wires may be placed above the longer wires as long as the law of projection stated is adhered to. When perfect addition of radiation is to take place at an angle θ to the horizon, the stagger distance X is then given by

$$X=\frac{(2N-1)\frac{\lambda}{4}+S\sin\theta}{\cos\theta\cos\alpha}$$

this being the same relation as given previously except for a reversal of the sign before S sin θ. Such an arrangement is shown in Figure 5.

Figure 6 shows an arrangement of three V wires wherein there are two pairs of shorter wires, one above and one below the longer V pair. This has the advantage of greater concentration of radiation vertically.

Figure 7 shows an arrangement wherein several V's are placed one above the other, each being shorter than the one above and each fed in successive quarter phase relation.

Figure 8 shows a broadside arrangement of a number of systems placed side by side in order to increase the horizontal concentration of radiation.

The invention is not limited to systems wherein the V's lie in horizontal planes. Any of the arrangements described may be rotated 90° so that the wires lie in vertical planes. The radiated wave is then polarized in a vertical plane. Figures 9 and 10 show two such arrangements.

Any of the systems described may be adjusted for maximum radiation in the direction of the converging ends of the V's rather than in the direction of the diverging ends, merely by a reversal in the polarity of the feed lines between pairs.

If desired, the systems may be used without metallic connections to the reflectors since an adjustable wire pair may readily be used for tuning with excellent results.

I claim:

1. A uni-directional antenna system comprising two pairs of diverging conductors extending substantially longitudinally in the direction of desired transmission and placed one above the other, the conductors of one pair having lengths different from those of the second pair, and means for energizing said pairs in phase quadrature relation with respect to each other.

2. A uni-directional antenna system comprising more than two pairs of diverging conductors extending substantially longitudinally in the direction of desired transmission and placed one above the other, the conductors of at least one pair having lengths different from those of another pair, and means for energizing said pairs in successive quarter phase relation.

3. A uni-directional transmitting antenna system comprising two pairs of diverging conductors placed one above the other, the conductors of one pair having lengths different from those of the second pair, and means for energizing said pairs such that the waves radiated from one of them lead in phase the waves radiated from the other pair.

4. A uni-directional transmitting antenna system comprising two pairs of diverging conductors placed one above the other, the conductors of the lower of said pairs being shorter than those of the other, and means for energizing said lower pair such that the waves radiated therefrom lead in phase the waves radiated from the upper of said pairs.

5. An antenna system comprising a plurality of pairs of diverging conductors arranged in parallel planes and placed one above the other, the conductors of one of said pairs having lengths different from those of another pair, means for energizing said pairs of conductors, and means associated with said conductors for obtaining a phase displacement in space of the waves radiated from one of said pairs with respect to the waves radiated from the other of said pairs.

6. A uni-directional antenna system comprising a pair of linear conductors angularly disposed in a single plane with respect to each other, each conductor having a length which is long relative to the length of the communication wave, and another pair of angularly disposed linear conductors located below said first pair, the conductors of said second pair being shorter than the conductors of said first pair, and means for energizing said lower pair of conductors whereby the currents therein are in phase quadrature relation with respect to the currents in the upper pair.

7. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of half wave lengths long, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators, another pair of angularly disposed linear conductors of different length spaced away from said first pair a vertical distance, said second pair of wires being energized in such manner that currents therein are in phase quadrature relation in respect to the currents in the other pair.

8. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each conductor having a length which is long relative to the length of the communication wave at the operating frequency, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector formed by the conductors, and means for obtaining a uni-directional effect in said antenna system comprising another pair of linear conductors angularly disposed with respect to each other and spaced away from said first pair a vertical distance substantially equal to a quarter wave length and having different lengths than the wires of said first pair.

9. A uni-directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of half wave lengths long and open ended, and means for exciting the radiators whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, a second pair of linear conductors angularly disposed with respect to each other, and shorter than the conductors of said first pair, located below said first pair, said second pair of conductors being arranged to be energized such that the currents therein are in phase quadrature with respect to the currents in said first pair of conductors.

10. A system as defined in claim 9, characterized in this, that the currents in said second pair are in leading phase with respect to the currents in said first pair.

11. A system as defined in claim 9, characterized in this, that said vertical spacing between

said two pairs of conductors is substantially equal to a quarter wave length.

12. A uni-directional antenna system comprising two V shaped wire formations placed one above the other, each of said V formations comprising a pair of conductors angularly disposed with respect to each other, said wires having a length which is long relative to the length of the communication wave, the wires of one pair having lengths different from the wires of the other pair, and means for energising the lower of said two V formations in such manner that the current therein is in phase quadrature with the current in the upper V formation.

13. A uni-directional antenna system comprising two V formations placed one above the other, each V formation comprising a pair of wires angularly disposed with respect to each other, each wire being long relative to the length of the communication wave, the wires of the lower V being shorter than the wires of the upper V, and the distance between the end of one of the wires on the lower V and the corresponding wire of the upper V being such that when projected upon the line of desired maximum radiation the projection is an odd number of quarter waves.

14. A V-type directional antenna system comprising a pair of conductors angularly disposed with respect to each other and arranged in a single plane, a second pair of conductors angularly disposed with respect to each other and parallel to said first pair of conductors and spaced therefrom a vertical distance, said second pair of wires being shorter than said first pair, means for energising said two pairs of wires such that the currents in both pairs are in phase quadrature relation with respect to each other, the horizontal distance between the ends of the corresponding wires of the first and second pairs being equal to

$$\frac{(2n-1)\lambda/4}{\cos\alpha}$$

where n is an integer, λ is the wave length, and α the half angle of the V.

15. A uni-directional transmitting antenna system comprising two pairs of diverging conductors placed one above the other, the lower of said pairs being shorter than the other, and means for energising said lower pair such that the waves radiated therefrom lag in phase the waves radiated from the upper of said pairs.

16. A broadside antenna arrangement comprising a plurality of pairs of diverging conductors extending substantially longitudinally in the direction of desired transmission and placed one above the other, and means for energising said pairs in successive quarter phase relation, and additional pairs of diverging conductors placed adjacent and on one side of said first pairs and similarly arranged with respect to each other to extend in the direction of desired transmission.

17. A uni-directional antenna system comprising a plurality of pairs of diverging conductors, each pair comprising wires extending substantially longitudinally in a vertical plane in the direction of desired transmission and placed one above the other, and means for energising said pairs in successive quarter phase relation.

18. A uni-directional antenna system comprising two pairs of diverging conductors extending substantially longitudinally in the direction of desired transmission and placed one above the other, the conductors of one pair having lengths different from those of the second pair, and means for energising said pairs in phase quadrature relation with respect to each other.

19. A V-type directional antenna system comprising a pair of conductors angularly disposed with respect to each other and arranged in a single plane, a second pair of conductors angularly disposed with respect to each other and parallel to said first pair of conductors and spaced therefrom a vertical distance, said second pair of conductors being shorter than said first pair, means for energising said two pairs of wires such that the currents in both pairs are in phase quadrature relation with respect to each other, the horizontal distance between the ends of the corresponding wires of the first and second pairs being equal to

$$\frac{(2n-1)\lambda/4-S\sin\theta}{\cos\theta\cos\alpha}$$

where n is an integer, γ is the wave length, α half the angle of the V, S is the spacing between the upper and the lower wires and θ is the angle of maximum radiation to the horizon.

20. A V-type directional antenna system comprising a pair of conductors angularly disposed with respect to each other and arranged in a single plane, a second pair of conductors angularly disposed with respect to each other and parallel to said first pair of conductors and spaced above said first pair a vertical distance, said second pair of conductors being shorter than said first pair, means for energising said two pairs of conductors such that the currents in both pairs are in phase quadrature relation with respect to each other, the horizontal distance between the ends of the corresponding wires of the first and second pairs being equal to

$$\frac{(2n+1)\lambda/4+S\sin\theta}{\cos\theta\cos\alpha}$$

where n is an integer, γ is the wave length, α half the angle of the V, S is the spacing between the upper and the lower wires and θ is the angle of maximum radiation to the horizon.

21. A unidirectional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of half wave lengths long and open ended, and means for exciting the radiators whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, a second pair of linear conductors angularly disposed with respect to each other and shorter than the conductors of said first pair, located above said first pair, said second pair of conductors being arranged to be energised such that the currents therein are in phase quadrature with respect to the currents in said first pair of conductors.

22. A unidirectional antenna system comprising two pairs of diverging conductors, the corresponding conductors of said pairs being placed one above the other, the conductors of one pair having lengths different from those of the second pair, and means for energising said pairs such that the waves radiated from one of them lead in phase the waves radiated from the other.

23. An antenna system in accordance with claim 22, characterised in this, that said pairs of conductors are in the same vertical plane.

24. An antenna system in accordance with claim 22, characterised in this, that each pair of conductors is in a different horizontal plane.

25. A unidirectional transmitting antenna system comprising two pairs of diverging conduc-

tors placed one above the other and located in different horizontal planes, the conductors of one pair having lengths different from those of the second pair, means for energising said pairs such that the waves radiated from one of them lead in phase the waves radiated from the other pair, and another similar arrangement of two pairs of diverging conductors arranged above said first two pairs, said last two pairs being also so energised that the waves from one of them lead in phase the waves radiated from the other.

26. A unidirectional antenna system comprising a pair of linear conductors angularly disposed with respect to each other, each conductor having a length which is long relative to the length of the communication wave, and two other pairs of angularly disposed linear conductors one placed above and the other below said first pair, the conductors of said first pair having lengths which differ from the conductors of said other two pairs, and means for energising said upper and lower pairs in phase quadrature with respect to said first pair of conductors.

27. An antenna system in accordance with claim 26, characterized in this, that the conductors of said first pair are longer than the conductors of said other two pairs.

28. A directional antenna system comprising a pair of conductors angularly disposed with respect to each other and arranged in a single plane, a second pair of conductors also angularly disposed with respect to each other and arranged in a plane parallel to said first plane but spaced away from said first plane, the wires of said second pair being shorter than the wires of said first pair, and means for energising said pairs such that the waves radiated from one of them lead in phase the waves radiated from the other pair.

PHILIP S. CARTER.

Certificate of Correction

Patent No. 2,027,020. January 7, 1936.

PHILIP S. CARTER

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 29, beginning with the word "So" strike out all to and including "18.5°" in line 61, and insert the same after line 32, second column of same page; second column, line 24, strike out the formula and insert instead $d \cos\theta \cos\phi \cos\alpha + d \sin\phi \sin\theta = (2N-1)\lambda/4$; line 41 (last line of equation), for "cos" read *sin*; page 4, second column, lines 20 and 41, claims 19 and 20 respectively, for greek letter gamma γ read λ; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of April, A. D. 1936.

[SEAL]

LESLIE FRAZER,
Acting Commissioner of Patents.

DEFENDANT'S EXHIBIT V

TRANSLATION

ANNALAN DER PHYSIK, 1908, M. ABRAHAM

Beginning page 465, Paragraph 7, Summary and Discussion of Findings.

We set out to solve the problem of determining the natural oscillations of a Hertzian exciter by way of integrating Maxwell equations. After the fundamental equations of Maxwell's electrodynamic had been brought into a form suitable for the purpose by the introduction of general orthogonal coordinates, we investigated the dependence of the frequencies and decrements of the natural waves upon the dimensions of the exciting source as well as upon the dielectric constant of the surrounding medium. In making considerations of this kind, recourse is often had to the notion of capacity taken from electrostatics; however, since with fields varying with time the definition of this term becomes invalid, we preferred to derive directly from the basic equations the following laws:

I. The frequencies of the natural oscillations of a Hertzian exciter are proportional to the root of the dielectric constant of the surrounding medium.

II. The logarithmic decrement of the damping of radiations of a Hertz exciter is independent of the dielectric constant of the surrounding medium.

III. The frequencies of the natural oscillations of geometrically similar exciters behave relative to one another as the lengths of corresponding stretches.

IV. The natural oscillations of geometrically similar exciters have the same logarithmic decrement.

V/.

The natural oscillations are determined by the following conditions. Throughout the entire field there hold good Maxwell's equations, at the boundary of the exciter the electric force lines terminate at right angles, and at great distance there exist only waves traveling away from the exciter.

We assumed the electromagnetic field to be symmetrical to the axis of rotation of the exciter and we determined the points of the meridian plane by the aid of a system of co-focal ellipses and hyperbolas. For a rod-shaped conductor, i.e., in the case of a very elongated ellipsoid of revolution it was feasible to find an infinite number of solutions of the fundamental equations and limiting conditions representing damped oscillations in such a way that the functions determining the electromagnetic field are represented in the form of the product of a quantity variable only along the ellipses and a quantity variable only along the hyperbolas. The half waves of these natural oscillations, in the first approximation, were equal to integral parts of the rod-length. Hence, this result is found:

V. The Maxwell theory admits of the existence of an infinitely great number of nearly harmonic overtones of the rod-shaped conductors.

Regarding the symmetry properties of the field of the natural oscillations the following may be stated:

VI. In the case of the fundamental oscillation as well as of all odd-numbered natural oscillations, in two points symmetrically situated in reference to the equatorial plane, the magnetic forces are equal. The electric charges of symmetrically located points of the conductor have opposite signs.

VII. In all even-numbered natural oscillations, in two points positioned symmetrically in reference to the equatorial plane, the magnetic forces are equal and opposite; the electrical charges of symmetrically located points of the conductor have the same sign.

What follows from this last rule is that for the even-numbered oscillations in the equatorial plane, the magnetic force disappears; in other words, advancing waves will not arise there at all. Hence, the frequencies to be observed in the symmetry planes are as 1:3:5:7, etc. Nothing is altered in this situation by guiding the waves along a wire, provided that the arrangement is symmetrical. Symmetrical conductor points will always be charged in the same manner by even-numbered oscillations, hence no potential difference prevails between such points. In other words, the existence of even-numbered oscillations is not ascertainable at all by measurements made in the symmetry plane. Now, Lamotte* has recently investigated the oscillations sent out from a Lecher wire system and a Blondlot exciter. He made observations in the plane of symmetry and he discovered that in the Lecher arrangement oscillations arose whose frequencies were almost as 1:3:5, whereas in the Blondlot scheme there occurred also almost even ratios between the frequencies. The assumption made by Lamotte and Drude** that what is concerned here are harmonics or overtones of the exciter is thus in full agreement with the above law in the case of the Lecher-wire arrangement, but not in the Blondlot scheme. Now, while our theory refers, strictly speaking, only to the rod-shaped conductor, this case nevertheless may be regarded as typical for all forms of exciter in which only proximately harmonic overtones arise. It is therefore likely that the oscillations

* - M. Lamotte, Wied. Ann., 65, pp92-105, 1898
** - l.c. p104.

noted in the Blondlot arrangement may, in part, not be interpreted as being harmonics of the exciter circuit, but may be ascribable to interactions between the primary and the secondary lines."

The current distribution corresponding to the natural oscillations along the conductors turns out to be very simple in the presence of vanishing radiation. The nodal points of the current are only a half-wave spaced apart from one another, also the ends of the rod must be regarded as nodes. The notion customary in wire waves which regards the oscillatory state as resulting from waves reflected at the free end of the wire with reversal of sign of the current leads to the same result. That this conception is untenable, however, will be evident when an investigation is made of the electromagnetic field at some distance from the conductor. For, as shown by theory, the nodal surfaces of the magnetic force are by no means planes, but rather:

VIII. The nodal surfaces cut the meridian planes in hyperbolic branches whose foci are located at the ends of the wire.

This immediately follows from the fact that the particular solutions corresponding to the natural oscillations are representable as the products of a function variable only along the ellipses and a function being variable only along the hyperboles. For if the magnetic force vanishes at some points of the conducting ellipsoid, it disappears along the entire "cup" of the con-focal hyperboloid of revolution containing the point in question. Rule No. VIII furnishes an explanation for certain experiments made by Sarasin and Birkeland.**

*-See J. v. Gleitler, Wied. Am., 57, p.412, 1896, and E. Marx, Diss. p.9 Gottingen, 1899, J. v. Gleitler, Sitzungsber. Scientific Society of Vienna, 107. IIa July, 1898.

**-I.S.A. R. Compte Rendue, 117, p.618-622, 1893.

These investigators examined the field in the neighborhood of a free-ended wire with a spark resonator and they found the nodal lines to be curved, with the concave face turned towards the free end. Theory, as a matter of fact, would indicate that the nodal lines in the vicinity of the free end would approximately have the shape of parabolas whose focus coincides with the end of the wire.

The emitted waves constantly extract energy from the electromagnetic field of the emitter and thus cause damping of the oscillations. If a/b is the ratio of rod-length and the radius of cross-section, and if we make

$$\varepsilon = \frac{1}{4. \log \text{nat} \left(\frac{a}{b}\right)}$$

then, in first approximation, the values of the decrement, for the fundamental wave (n = 1) will be:

$$\sigma_1 = 0,74\ \varepsilon,$$

for the first harmonic (n = 2):

$$\sigma_2 = 0,25\ \varepsilon,$$

but for all higher orders

$$\sigma_n = \frac{2,06 + 4. \log \text{nat} (n)}{n} \cdot \varepsilon.$$

Hence, it will be noted that:

II. The decrements of natural oscillations of the rod-shaped conductor constantly decrease with growing ordinal number. The time-damping on the contrary, grows with growing ordinal number.

In other words, the harmonics decay faster than the fundamental wave, and yet the amplitudes of the harmonics decrease only after a greater number of oscillations to a definite fraction of the initial value. The damping by radiation becomes vanishingly small as the cross-sectional area of the rod diminishes.

Radiation modifies the current distribution along the conductor. In the presenceof vanishing damping, the same could be regarded as the result of a wave traveling towards the free end and a wave reflected at the latter with the same amplitude, but reversed sign of the current. The influence of the radiation upon the oscillatory state has recently been investigated by Rokotrov* and this author believes that the same could be taken into consideration by introducing for the reflection at the end of the wire phase loss and a reduction of amplitude. However, from our own viewpoint, and for waves along a single wire, this supposition would not appear justified. For since the function $E_n(y)$ which represents the distribution of the current along the wire disappears when $y = \pm 1$, i.e., at the wire ends, there will occur there always a node of the current. What thus follows from law No. VIII is that the extensions of the wire axis are nodal lines of the magnetic force. Hence, the oscillation energy does not radiate in an axial direction, but rather in a lateral direction. The assumption may therefore be made that the influence of radiation makes itself manifest during the progression along the wire rather than upon reflection at the free end. As a matter of fact, what has been proved is this:

* - E. Wied, Ann. 64, p317,1898

REFLECTION -

ANNALEN DER PHYSIK - 1900, Page 486 - M. ABRAHAM

4. The Electric Oscillations Around a Linear Conductor, Treated According to the Maxwell Theory. By M. Abraham.

Page 492 -

E. If one looks upon the current distribution caused by the natural periods as composed of the superposition of a wave train traveling out toward the open end and of one reflected back from the open end, there is found progressively along the length of the conductor a continual change in the amplitudes and phases of both waves. There is complete reflection at the open end.

When the effective value is measured with a bolometer or thermocouple, then its distribution lengthwise of the conductor is expressed as a first approximation, i.e., neglecting magnitudes of the order of β^2, by $\cos^2(\frac{\pi}{2}\frac{x}{\lambda})$ for the odd numbered and by $\sin^2(\frac{\pi}{2}\frac{x}{\lambda})$ for the even numbered periods.

At a great distance from the antenna the ellipse x = const. and the hyperbola y = const. which are determined by the position of a point in the meridian half plane become respectively a circle of radius x and a straight line, which makes an angle φ = arc cos y with the axis of the antenna. We are here in the region of waves traveling away from the antenna. The radial component of the electric force vanishes in comparison with the components of the electric and magnetic force standing at right angles to the direction of propagation and which are determined by the real part of, $\frac{e^{\beta_0(x-ct)}}{x}\quad\frac{E_0(y)}{\sqrt{1-y^2}}$

Therefore, the variation of the intensity of radiation along a meridian is expressed by the absolute magnitude of the function. 7 39 V/1

Page Tightly Bound

$$\frac{E_m^2(y)}{r-y^2} = \frac{E_m^2(\cos\varphi)}{\sin^2\varphi}$$ which, as a first approximation

is proportional to,

$$\frac{\cos^2\left(\frac{\pi m}{2}\cdot\cos\varphi\right)}{\sin^2\varphi}$$ for the odd numbered and

is proportional to,

$$\frac{\sin^2\left(\frac{\pi m}{2}\cdot\cos\varphi\right)}{\sin^2\varphi}$$ for the even numbered

periods.

XI. If the radiations given off from the Hertzian exciter comprise oscillations of different periodicities, then the share of the various constituent natural oscillations in the aggregate radiation intensity will differ for different points of a meridian.

If, on the contrary, the distribution of the total radiation of the rod-shaped exciter along a meridian is known, our findings probably enable us to decide the question whether only the fundamental wave is sent out or whether an appreciable portion of the aggregate radiation corresponds to the harmonics.

In the second approximation, i.e., if quantities of an order λ^2 are taken into consideration, a correction is necessary in the above-mentioned values of the wave-lengths and the decrements, by that a certain fraction must be added to the length of the rod in order that an integral multiple of the half-wave of the natural oscillation in question may be obtained. The said fraction was

$3.6 \times \lambda^2$ for the fundamental wave ($n = 1$)

$3.9 \times \lambda^2$ for the first harmonic ($n = 2$)

$\frac{4.8 + 2 \log \text{nat } (n)}{n} \times \lambda^2$ for all higher harmonics.

Hence, it will be noted that:

XII. The correction to be made in the length of the rod in order that an integral multiple of the half-wave may be found, steadily decreases with increase in ordinal number.

In other words, the wave-lengths of the harmonics are invariably slightly smaller than what would correspond to perfect harmony with the fundamental.

In conclusion I feel it an agreeable duty to express my gratitude to my esteemed teacher and superior Prof. M. Planck, for his friendly interest in connection with my above research work.

Physikalische Zeitschrift,

Second Year, March 8, 1901,
Pages 329-334

Spark Telegraphy and Electrodynamics

By M. Abraham.

When Heinrich Hertz discovered the property of the electric spark of resulting in very rapid electrical oscillations, he made an attempt to decide between the various electrodynamic theories advanced at that time. His investigations convincingly confirm Maxwell's theory, in fact, they showed that electric waves travel at the speed of light into the ether, and that, as asserted by Maxwell, they differ from light waves only in that they are of a greater wave-length.

Telegraphic communication or signaling by the intermediary of Hertzian waves over relatively great distances, known as spark telegraphy, was carried into practise first by Marconi. In this connection in constrast with laboratory arrangements, a number of modifications proved expedient. At the exciter was mounted a vertical wire; from the latter, the sending wire, waves are radiated off in all directions into ether and they carry the telegraphic signals to the receiving station. At the latter is disposed a similar wire which picks up these waves. The resistance alterations of a coherer serve as a reagent to the electrical oscillations of the receiving wire.

Of late, Slaby and Count Arcol succeeded in introducing a progress in the art of spark telegraphy in that they tuned a sending and a receiving wire to each other. The circumstances that such tuning is feasible admits of the presence of regular oscillations of definite frequency in the wires. Then, as would be suggested by the acoustic analogy and has been confirmed by experiments made on electric resonance, the "intensity" of resonance or consonance f

the receiving wire would essentially be a function of the frequencies and the decrements (of damping) of the natural periods of the two wires. If the damping of the transmitter is marked, and that of the receiver low, then the receiver will oscillate at the frequency of its own natural oscillations irrespective of what may be the frequency of the transmitter; if, on the contrary, the damping of the receiver is great in contrast to that of the transmitter, the receiver will be caused to vibrate at the frequency of the incident waves. If tuning as pure as possible is to be attained, then not only the frequencies of both outfits will have to be consonant, but at the same time the damping should be diminished.

Now, the question may be posed as to what factors are decisive so far as the damping of electrical oscillations is concerned? In the case of a.c. of low frequency, it is primarily the line resistance of the wires; but at high frequencies such as are used in spark telegraphy, the damping due to radiation plays a by no means inferior role. The waves which serve as the carriers of telegraphic signals convey a certain amount of energy; this energy is withdrawn from the oscillations of the sending wire, and the amplitudes thereof are thus caused to be diminished more and more. The damping due to radiation therefore is inevitable in spark telegraphy.

The methods known from theoretical electrodynamics make it possible to estimate the various damping factors. They govern the distribution of the current along the wire, the propagation of waves in the ether, the radiated energy and the energy dissipated in the conductor.

The first query; In what way do electric waves propagate along a conducting wire, and of what effect is the free end? The laws underlying the propagation of electrical disturbances along an infinite wire possessing high conducting powers, formally speaking, are in agreement with the known motional

laws of the stretched wire. However, the physical nature of the two phenomena would be substantially dissimilar. For in the case of a mechanical wave, the seat of the vibrational energy would be in the very wire, while for the electric wave it is in the surrounding ether. The wire here serves merely for the conducting away of the waves; the electrical current is confined to the outermost boundary layer of the conductor, the interior of which being screened from the electrical and the magnetic forces. Now, it may be asked, what happens when the wave reaches the free end F of the wire (Fig. 1)? In the case of the mechanical wave, complete reflection takes place. Is the electrical wave also simply reflected at the free end? At first blush, this might be thought impossible, for the wave continues propagating beyond AFB into ether. In what way will this circumstance affect the oscillatory phenomenon?

The Author, in two articles, has made an attempt to explain the phenomena in the field of a free-ended conducting wire looked at from the viewpoint of Maxwell's theory. The first study (1) dealt with the natural oscillations of a wire of finite length, whereas the second study (2) more exhaustively deals with forced oscillations of a unilaterally bounded wire and proves the agreement between the theory and the present observations. It was found that the assumption of complete reflection at the free end is approximately fulfilled. The disturbing effect of the free end essentially resides in a slight distortion

(1). Wied. Ann. 66, 433-472, 1898, later referred to as I

(2). Drude's Ann. 2, 726-761, 1900, later referred to as II

of the waves (3). If the waves are of a definite frequency, then standing oscillations are produced, with a current node being located at the free end. At intervals each of a half-wave length there arises another node of the current. The displacement of the node positions in the vicinity of the free end is very slight (4). The wire may be cut at a second place but this second place must be at a nodal point of the current if it is desired to preserve the wave system on the now bilaterally bounded wire. Hence, the double length of the wire is an integral multiple of the wave-lengths of its natural oscillations. This finding corresponds to that of Slaby and the basic notion adopted by him respecting the distribution of the current in the sending and the receiving wires.

If, then, this assumption respecting the current distribution confirmed by theory be accepted, it will be possible to survey the course of the radiation process in spark telegraphy without any undue amount of mathematical auxiliaries. I beg to explain this situation by the simplest example. The results of the approximation method are in proper agreement with the exact theory previously suggested by this Author.

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(3). II pp. 33, 40

(4). II pp. 36,38

SPARK TELEGRAPHY AND ELECTRODYNAMICS, by M. Abraham.

(Published in the Physikalische Zeitschrift, No. 22, March 2, 1901, 2. Jahrgang, pages 329 to 334. This translation begins at the second paragraph of the second column on page 330 and ends at the first paragraph of the first column on page 332.)

A wire EP (Fig. 2) of length l rises vertically upwards from the earth. The earth is to be considered a perfect mirror for electric waves.

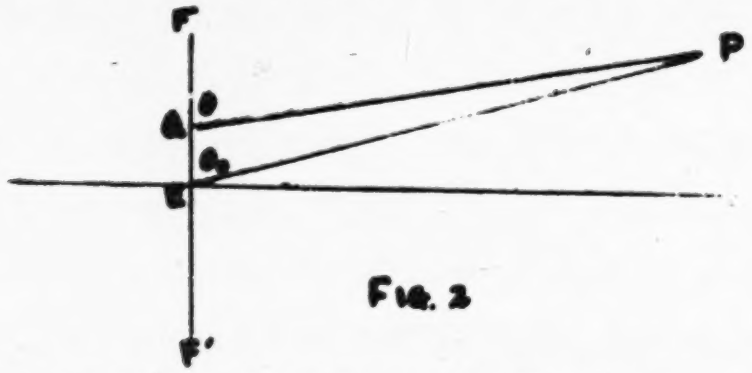


Fig. 2

The earth point E is a node of electric potential. The wire is now reflected with respect to the earth's surface and the potential distribution is chosen in such a manner that the opposite potentials are prescribed by two corresponding reflected points, one on either side, thus is the electromagnetic field of the wire EP above the earth identical with that of the wire FF' of length 2l oscillating in free space.

Therefore, we investigate the natural oscillations of a wire which has a node of potential at the middle point E and, consequently, an antinode of currents; these are the odd numbered natural oscillations. Its current distribution is determined by

$$\mathfrak{J} = a \cos\left(\frac{\pi n}{2l}\eta\right) \cdot \sin\left(\frac{\pi n c t}{2l}\right)$$

$$-l \leq \eta \leq +l.$$

Here η expresses the height of any section A above the middle point E of

V°/8 H

the wire, t the time, c the velocity of light, a the amplitude of the current oscillations at the antinode of current. An odd positive whole number is to be substituted for n which designates the ordinal number of the oscillation. This swiftly changing current now sends out waves of electromagnetic induction.

The electromagnetic field of an oscillating current element has been determined by H. Hertz. Let Q be the middle point of the current element F ds. Furthermore, let P be a point in space whose distance PQ = r from the current element is large compared with the wavelengths of the oscillations. Then the electric force (E) lies in the plane including P and the wire, and is perpendicular to PQ; the magnetic force (H) is perpendicular to that plane. The intensities of both forces are determined by

$$E = H = -\frac{d}{dt}\left(\frac{Jt-\frac{r}{c}}{r}\right)\cdot ds\cdot \sin\theta$$

$$= a\cdot\frac{\pi n}{2l}\,ds\cos\left(\frac{\pi n\gamma}{2l}\right)\frac{\cos\frac{\pi n}{2l}(ct-r)}{r}\sin\theta$$

The disturbance leaving Q at time $(t-\frac{r}{c})$ arrives at P at time (t). This is a deduction from the general equation which states that electric induction is propagated with the velocity of light.

The magnetic forces which come from the individual current elements are pointed in the same direction, namely, perpendicular to the plane EFP. Likewise the electric forces do not deviate appreciably in direction if we make the assumption that r is large compared with the sum of all the wavelengths of the natural oscillations, i.e., large compared with 4 l.

For the differences in direction of straight lines drawn to the individual current elements diminish with the increasing distance from the wire. Accordingly, the electric forces sent out from the individual current elements are perpendicular to the straight line EP drawn through the middle point E. Let r_0 be the length, $\Theta = PEF$ the angle, which it forms with the wire axis. Then with this approximation we have

3) $$r = r_0 - \eta \cos\Theta$$

4) $$H = E = a \cdot \frac{\pi n}{2l} \cdot d\eta \cos\left(\frac{\pi n}{2l}\eta\right) \frac{\cos\frac{\pi n}{2l}(ct - r_0 + \eta\cos\Theta_0)}{r_0} \cdot \sin\Theta_0 .$$

Now all the electric and likewise all the magnetic forces coming from the individual current elements are superposed. For the equations linking the electromagnetic field in the aether and the current in the conductor are linear equations. Accordingly, one obtains for the resultant intensity of the electric and magnetic forces at a distance r_0 from the middle point of the wire large compared with 4 l

5) $$H = E = a \cdot \frac{\pi n}{2l} \cdot \frac{\sin\Theta_0}{r_0} \int_{-l}^{+l} d\eta \cos\left(\frac{\pi n}{2l}\eta\right) \cdot \cos\frac{\pi n}{2l}(ct - r_0 + \eta\cos\Theta_0).$$

Since n is odd, we have

$$\int_{-l}^{+l} d\eta \cos\left(\frac{\pi n}{2l}\eta\right)\cos\left(\frac{\pi}{2l}\eta\cos\Theta_0\right) = \frac{+l}{\pi n} \cdot 2\sin\left(\frac{\pi n}{2}\right) \frac{\cos\left(\frac{\pi n}{2}\cos\Theta_0\right)}{\sin^2\Theta_0}$$

v/n

and we obtain

$$6)\quad H = E = 2a(-1)^{\frac{n-1}{2}} \cdot \frac{\cos\frac{\pi n}{2R}(ct-r_0)}{r_0} \cdot \frac{\cos\left(\frac{\pi n}{2}\cos\theta_0\right)}{\sin\theta_0}$$

This electromagnetic field corresponds to a spherical wave, which spreads out rapidly from the middle point of the wire. We consider a sphere r_0 = constant, and construct circles of longitude and latitude where we regard as the poles the points at which the extensions of the wire axis pierce the sphere. The magnetic force is everywhere in the direction of the circles of latitude, the electric force being oriented in the direction of the meridians. Both are perpendicular to the direction of propagation of the wave. The intensities of the forces vary with the latitude θ_0 according to the equation

$$\frac{\cos\left(\frac{\pi n}{2}\cos\theta_0\right)}{\sin\theta_0}$$

Accordingly, for the fundamental oscillation (n = 1) the amplitudes reach their maximum value at the equator ($\theta_0 = \frac{\pi}{2}$). The most intense rays are sent out perpendicular to the wire axis. At the pole ($\theta_0 = 0$) the intensity is zero. For the fundamental oscillation the amplitude constantly diminishes from the equator to the poles. The harmonic oscillations, on the contrary, possess still other minima and maxima. The minima lie in the latitude circles determined by

$$\cos\theta_0 = \pm\frac{m}{n} \quad (m \text{ odd})$$

when

Since according to equation (1) the positions of the current nodes in the wire are given by $z = \pm \frac{n\lambda}{2}$, the node lines of the sphere can be found by the following construction. Hyperboloids are drawn through the current nodes in the wire and their foci fall at the ends of the wire (F, F^1). Their asymptotic cones cut the sphere in the node lines. The node lines mark the boundary lines of zones of oppositely phased oscillations on the sphere.

What energy is radiated into the ether by the waves? Clues may be found on this question by the aid of a law of electrodynamics advanced by Poynting which states that the energy flows at right angles to the electric, and magnetic forces. If, more particularly as in our own case, those two vectors are at right angles to each other, then the amount of energy flowing each second through a square centimeter of area of our sphere is

- (see text for equation) -

Integrating for the entire area of the sphere, this aggregate radiation is found:

- (See text for equation) -

The definite integral here arising can be converted into the following series: - (See text for equation) -

This last-mentioned definite integral I have designated by C_n (1) and for the same the following formula has been derived (1):

- (See text for equation) -

For the fundamental oscillation this formula results in

- (See text for equation) -

For the harmonics (n = 3,5,7,etc.) it furnishes with sufficient closeness:

- (See text for equation)-

Now, the total radiation per second becomes:

- (See text for equation) -

The energy which is extracted from the field of the oscillating wire in the time of a full cycle ($\tau = \frac{2l}{cn}$) is

- (See text for equation) -

With growing ordinal number n, in the presence of unvaried amplitude α of the current variations in the current loops, the energy radiated off during one oscillation constantly diminishes.

(1). I pp. 460,461

In order to ascertain the damping which is a result of radiation we must in addition calculate the electromagnetic energy of the oscillating wire itself.

The magnetic energy of a wire traversed by a uniform flux is

- (See text for equation) -

where L is the coefficient or inductance of the wire. In the practical application of this formula, we will in the first place have to keep in mind that, generally speaking, electric energy exists side by side with the magnetic energy. But if we pick the instant of crest current when according to equation (1)

- (See text for equation) -

then the electrical energy vanishes since momentarily no electrical charges exist on the wire. However, what must be kept in mind in the second place is that the flux is not uniform, indeed, that it changes from one cross-section to the next. It would be easy to form an average for the square of the current:

- (See text for equation) -

and thus to put

$$T = \frac{1}{2} La^2$$

Since the flow is confined to the surface layer the coefficient of self induction assumes value

- (See text for equation) -

where is the radius of the wire cross-section.

If, then, (9) which is the amount which is lost by radiation during a cycle be divided by (10) standing for the aggregate energy, the

following result is obtained:

In the course of a whole oscillation this fraction

- (See text for equation) -

of the energy is dissipated by radiation.

The logarithmic decrement of the oscillation amplitudes therefore is

- (See text for equation) -

It is very remarkable that the result of the complete estimate almost strictly agrees with the formula which an exact theory furnishes in first approximation for the logarithmic decrement or the damping of radiations, and which reads:*

- (See text for equation) -

Putting here

- (See text for equation) -

it will be noted that the departure from formulae (12) and (13) is very slight for wire dimensions such as occurring in practice.

We shall now calculate for a concrete case the amount of radiation damping numerically. Suppose we have a wire whose length is l = 50 meters, and whose cross-sectional radius = 0 .5 mm. Then

- (See text for equation) -

In the light of (8a) and (13), the decrement for the fundamental wave becomes:

- (See text for equation) -

* - I p.407 equs. 23a. $\mathfrak{C}$ is determined by equa. 17a, p.451. There the length of wire is 2 and the radius of the cross section b. The formula $\mathfrak{C} = 4 \mathfrak{m} \left(\frac{l}{b}\right)$ applies generally because in accordance with I, p.456, geometrically like conductors have the same logarithmic decrement.

On the other hand, the decrement of the damping shall be calculated which the oscillations experience as a result of line resistance in the wires. The absorption of waves which propagate along a line wire has been investigated by A.Sommerfeld.* In our instance, the approximate formula** will suffice which for the fundamental wave furnishes the logarithmic decrement:

- (See text for equation) -

where μ is the (magnetic) permeability, C the conductance measured in terms of absolute electromagnetic units. For copper wire there is $\mu = 1$, $C = 6 \times 10^{-4}$. Hence

- (See text for equation) -

While as a result of heat dissipation in the wire the amplitude would decrease to the 2.718th part of its initial value after only 80 cycles, this same decrease is caused by radiation already after 5 cycles.

This finding is by no means surprising. For, as above pointed out, it is distinctly desirable so far as the purpose of spark telegraphy is concerned, that the energy should not be lost as a consequence of absorption inside the conductor, but should be caused to be radiated off in order to utilize the same for telegraphic signals and their transmission.

* A. Sommerfeld, Wied. Ann. 67, 233-290, 1899

** l.c.S. p.276, $X\lambda_0$ is here equal to $v_1 \cdot \lambda_0 = 4l$

In laboratory experiments, on the contrary, arrangements have frequently been used in which the radiation loss is diminished as much as possible in order to avoid disturbances occasioned by reflections on the wall of the room, and, on the other hand, in order to secure oscillations persisting for a long while. The electric waves have been guided along two parallel wires (CD, C'D', Fig. 3), being spaced apart a distance that is small compared with the wavelength in such a way that two opposite points Q, Q' of the two wires were caused always to oscillate in phase opposition. Both of the opposite current elements thus furnish or contribute equal and opposite values to the intensities of the electrical and the magnetic force of the emitted wave. Hence, the radiation in such a closed system is insignificantly small when contrasted with the radiation of a single freely oscillating wire (1).

It has been found that in a vertically rising wire the decrement of the fundamental wave may not be diminished below 1/8. Prof. Slaby and Count Arco have used for the receiver also an arrangement in which from the grounding point E a line EK being horizontal and of like length as the vertical was used which at itsfree end K, at the point of maximal potential, was fitted with the coherer.

(1) The same thing applies to oscillations produced by the discharge of a Leyden jar. As stated by Prof. Braun in a recent paper such oscillations are also successfully used in wireless telegraphy. A much smaller fraction of the oscillating energy will thus be utilized in the transmission of the signals but the tuning seems to be more perfect.

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In this instance, there holds good for the horizontal wire EK what has just been stated. If it be close to the surface of the earth, it furnishes conjointly with its image E'K' in reference to the surface of the earth, no appreciable contribution to the radiation. On the contrary, the horizontal line contains a quantity of electromagnetic energy which is at least equal to that of the vertical line or wire. In this disposition the loss due to radiation at most may be deemed to be 1/10th.

Although the method here used would, a priori, not appear free from objections, the agreement between the results thereby found and the finding of the exact theory demonstrates and justifies its raison d'être. In fact, it likely that the same could successfully be employed also in the case of more complicated arrangements in which the exact theory is a failure.

TRANSLATION

A.D.P., February 23, 1937 -

MEASUREMENTS IN THE RADIATION FIELD OF ROD-SHAPED ANTENNA EXCITED IN THE FUNDAMENTAL AND HARMONIC FREQUENCIES

By L. Bergman

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6. A linear antenna energized in its third harmonic.

The total length of antenna $2l$ = 344 centimeters. Since we are dealing with an even number harmonic and there is therefore a current node in the middle of the antenna, the excitation was not symmetrical. Fig. 22 shows the current distribution on the antenna and the position in which the sender excites the antenna is specially indicated. The dotted curve interconnecting small circles illustrate the experimentally determined radiation diagram. The curve indicated in full lines is calculated in accordance with the equation

The total radiation of the antenna falls into four parts. The radiation will be 0 for the values; cos θ =1, 1/2, 0, i.e., for $\theta = 0^\circ$ (direction of antenna), $\theta = 60^\circ$, $\theta = 90^\circ$ (equatorial plane), $\theta = 120^\circ$ and $\theta = 180^\circ$ (antenna direction). The experimental data corresponds perfectly with the calculations so far as the direction of the radiation is concerned. However, this is not true for the amplitude of the radiation lobes. In accordance with the calculation, the lobes inclined towards the equatorial plane should be substantially smaller in amplitude than the lobes radiated at a sharp angle with respect to the direction of the antenna. This relation is approximately true for the right half of Fig. 22; the larger lobe is

V/as

somewhat small because the amplitude of the currents in the individual current loops on the antenna are different. On the other hand, in the other half of the radiation diagram, the positions of the two radiation components are interchanged. The reason for this is the unsymmetric excitation of the antenna producing different currents in the two halves of the antenna. The ratios are the same as in the above discussed case, in which the antenna was excited at its second harmonic. On account of the unknown current relations, these ratios can be calculated only with a great deal of trouble.

11. Rod-shaped Antenna excited by the Sixth Harmonic.

The length of the antenna which in this instance is excited again symmetrically in the middle was 7/2 λ = 602 cm. Fig. 28 shows the measured radiation diagram and the radiation diagram calculated by the equation:

-(See text for equation) -

The radiation of the antenna is here divided into seven parts. The number of the lobes of radiation produced, just as in the instances hereinbefore dealt with, is always in agreement with the number of current loops existing along the aerial. Zero places of radiation are at cos ϑ = 1, 5/7, 3/7, 1/7, 0, i.e., at ϑ = 0 degree (direction of antenna), 44°25', 64°38', 81°48', or the places corresponding to the mirror images in reference to the equatorial plane. The presence of these zero points and of the corresponding lobes of radiation is exactly confirmed by the measurements. Discrepancies are found only as regards the energy amplitudes radiated off from the various lobes. The major part of the energy, however, just as in the previous case, is given off at an acute angle to the antenna direction. It is just these last two cases which go to show that in the transmission on short waves it is feasible by the use of an antenna being positioned perpendicular to the surface of the earth, and which is excited by a harmonic, to cause the major portion of the energy to be radiated off obliquely in upward direction at an acute angle in reference to the direction of the aerial. This portion of the energy leaves the antenna in the form of a space wave. When working with waves of great length, on the contrary, we are mostly dealing invariably with a surface radiation seeing that the antenna, for reasons of the great antenna height which is not realisable in actual practice, is unable to be excited by harmonics.

1. There is described the construction of a tube transmitter for the generation of undamped oscillations with a wavelength of 172 cm. which is arranged to excite a rod-shaped conductor antenna in any of its even and odd numbered harmonic periods.

2. By means of a specially constructed receiver, the radiation field is measured of an antenna excited respectively in its fundamental and different harmonic periods. The measurements are carried up to the excitation of the antenna in its sixth period.

With excitation at the fundamental period, the entire radiation is perpendicular to the antenna in its equatorial plane. But when one proceeds to excitation in the harmonic periods there results radiation from the antenna in several directions, and, in fact, there are just as many directions of radiation as there are current antinodes over the whole antenna. There is very good agreement between the measured radiation diagrams and the radiation curves calculated by the Abrahams equations in respect to the direction of the radiation branches. For the amplitude of the energy radiated in the separate directions there is, on the contrary, a departure between calculation and measurement. The reason lies in this, that hitherto in calculating it was always assumed the the current amplitude in the individual oscillating antinodes on the antenna all had the same value. In reality, however, the current amplitude in that current

LL V/21

antinode where the excitation by the transmitter takes place is substantially greater than in the neighboring current antinodes. When this is considered in the calculation, then the amounts of energy transmitted in the individual directions is in agreement with the measured values also in regard to amplitude.

3. In several cases, by the insertion of coils, the radiation from individual antinodes is suppressed and thereby a special radiation diagram results which is, nevertheless, in agreement with the calculations.

4. The results obtained are of practical value because today wireless telegraphy is carried on over great distances by the use of short waves of less than 100 meter wavelengths. By exciting the transmitting antenna in harmonic periods one can send out the greatest part of the radiated energy, not as hitherto with the long wavelengths perpendicular to the antenna and, consequently, parallel to the earth's surface, but at more or less of an angle with the antenna and, accordingly obliquely upwards, and thereby to radiate directly skyward which is especially well suited for the propagation of short waves.

TRANSLATION - Annalen Der Physik - 1926 - Pages 425-435.

A RADIATION FROM COMPLICATED RECTANGULAR ANTENNAE WITH SPECIAL RADIATORS

By M. A. Bontsch-Bruewitsch

I. Radiation Resistance.

a) By a complicated antenna will be meant an aerial which consists of a number of radiators and a system of wires by means of which the energy is supplied. By a rectangular antennae the author means those in which the wires are arranged only in three mutually perpendicular directions. Accordingly the axis of these radiators are directed in one of these three directions.

The radiation resistance of an antenna or this kind may, in general, be defined as the ratio of the radiated power P to the square of the sum of loop currents in the various radiators. In the case of n similar radiators through which flow equal currents this resistance

$$R = \frac{P}{(ni)^2} \qquad (1)$$

In general the losses divide themselves among the radiators unequally. In practice it is often preferable to deal with the average value of radiation resistance of each radiator. This average value may be determined as follows:

$$r = \frac{P}{ni^2} = nR \qquad (2)$$

Before we proceed with the discussion of radiated power from antenna systems, we wish to emphasize the following fact: If r_0 is the radiation resistance of a single isolated radiator and r is the corresponding resistance of the same radiator when it is functioning in conjunction with other radiators in a complicated antenna then $r_0 \neq r$ as long as there is

V/10

interaction among the radiators which results in new electromotive forces. These electromotive forces could be calculated independently of the distribution of radiation and thus r could be determined without any knowledge of radiated power. On the other hand, when determining the resistance from the radiated power it is necessary and sufficient to know only this power. From this point of view, the distribution of radiation in space is quite immaterial. This distribution could be changed by any secondary causes whatever, still as long as the radiated power remains the same the radiation resistance of the antenna does not vary. In other words the resistance remains the same as long as there is no interaction among the aerials of the system which would influence the radiation in space.

This remark holds equally true in case of the action of the earth which always, more or less, influences the distribution of radiation of an antenna. The influence of the earth on the radiation resistance can be considerable only in the case when the antenna is near the earth.

It is often assumed when calculating the radiation resistance of a conductor that the earth is a perfect conductor and that the antenna is strung quite near the earth. This however corresponds to no actual case then working with short waves for such antennas are elevated high above the earth and the earth itself cannot be considered as an approximately perfect conductor.

One may minimize these errors by treating the earth as an external mirror which is arranged in any fashion whatever and which has a certain definite absorbtion coefficient. The advantage of this mode of treatment lies in that it makes possible to apply the analysis for dealing with distribution of radiation as well as the calculations of resistance for any practical cases.

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When calculating the power we shall first assume that the aerial is removed far from the earth. The influence of the earth will be introduced later. The following method will be used in calculating:

Let us imagine that there are a number of dipoles of infinitesimal dimensions and at distances of half a wave length from one another at the center of a sphere, the diameter of which is so large that one may neglect the dimensions of the dipole system. The radiators are arranged along the axis SS_1 (Fig. 1) and the axes of these radiators are at right angles to the equatorial plane of the sphere. Let θ be the angular distance between M_1 and N and α, the azimuth of the great circle $N M_1$ perpendicular to SS_1 be chosen as the coordinates of M_1.

Since the radius of this sphere has been chosen to be so very large in comparison with the dimensions of the dipole system, we may regard the lines joining M_1 with the various dipoles as parallel. Let it be assumed that the oscillations of the dipoles are in phase and that these dipoles in phase and that these dipoles have equal moments. Let the amplitudes of the vectors which are produced by the individual dipoles on the surface of this sphere be $h_0 = f(\alpha, \theta)$. Then at point M_1 with coordinates α_1, θ_1, the magnetic component of the pointing vector due to the first dipole is

$$h_0 \sin \omega t = f(\theta_1, \alpha_1) \sin \omega t$$

The corresponding component due to the second dipole is

$$h_0 \sin (\omega t + \beta)$$

Where β is the difference in phase which corresponds to the difference in path $l \cos$ (Fig. 2)

V/N1

$$\beta = \frac{2\pi l}{\lambda}$$

The third dipole produces

$$h_0 \sin(\omega t + 2\beta) \qquad \text{etc.}$$

The resultant vector is

$$H_0 \sin\left|\omega t + \frac{\beta(n-1)}{2}\right| = h_0 \left[\sin \omega t + \sin|\omega t + \beta| + \cdots\cdots + \sin\left[\omega t + \beta(n-1)\right]\right|$$

By applying the series expansion

$$\frac{\sin n x \cdot \sin(n-1)x}{\sin x} = \sin 2x + \sin 4x + \sin 6x + \cdots + \sin 2x(n-1)$$

and by putting $\omega t = 0$ we obtain the ratio of the amplitude or the root mean square value of the resultant vector to the sum or the root mean square of the sum of the components:

$$(3) \qquad \frac{H_0}{h_0} = \frac{H}{h} = \frac{\sin\frac{n\beta}{2}}{\sin\frac{\beta}{2}} = Y_1$$

This quantity shall be called the phase factor and the function $Y = \psi(\alpha, \theta)$ which defines this phase factor, will be called the phase function. The form of this function depends on the number and on the arrangement of the radiators. Presently it will be shown that for all points along the arc of a small circle which is perpendicular to the axis SS_1 of the sphere the phase factor has the same value.

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Let us take another point M_2 somewhere on the arc of this type (Fig. 2 and Fig. 3) then OM_2 makes the same angle with BB_1 as the one made by OM_1 and therefore it is clear that the phase difference between the vectors due to any two neighboring radiators is the same as in the preceding case.

Accordingly,

$$H_0 \sin\left[\omega t + \gamma + \frac{\rho}{2}(n-1)\right] = k_0'\left[\sin(\omega t + \gamma) + \sin(\omega t + \gamma + \rho) + \cdots + \sin(\omega t + \gamma + n\rho + 1)\right]$$

Hence:

$$(4) \qquad \frac{H}{k'} = \frac{\sin\frac{n\rho}{2}}{\sin\frac{\rho}{2}} = Y_1$$

Now we wish to show that in the case of a linear conductor in which the current is distributed symmetrically with respect to the midpoint, the phase of the ve produced by the complete antenna is exactly equal to the phase produced by th current elements located at equal distances from the two ends of the antenna. The current amplitude along the length AB of the conductor AB (Fig. 4) may be defined as a function $i_0 = f(x)$, where (x) is the distance from the mid-point. The magnetic vector at a distant point M such that the line joining it wi th the center of this sphere makes angle θ is given as follows:

Page Tightly Bound

$$(5)\qquad \left\{ \begin{array}{l} dx - A \int_0^{\ell} f(x)\, L \sin(\omega t + \varphi) + \sin(\omega t - \varphi)\, dx = \\ = \left[2 A \int_0^{\ell} f(x) \cos\varphi \, dx \right] \sin \omega t - \beta \sin \omega t \end{array} \right.$$

Here $\varphi = \frac{2\pi}{\lambda} x \cos\theta$

elementary vector produced by an element of the conductor dx (when x = 0) the same time M is

$$(6)\qquad dh = [A f(0) \cdot dx] \sin \omega t = \beta_1 \sin \omega t$$

mparison of (5) and (6) shows that the two vectors differ in amplitudes t have the same phases. Thus, when one is trying to determine the phase ation of some antennae which satisfy the aforementioned conditions it is ssible to replace the antennae by dipoles situated at their mid-points. ese dipoles should be assigned the phases of the mid-points of the antennae. t us assume a linear antenna made up of identical elements which are so ranged that their mid-points are at equal distances d from each other and, reover, that within the limits of each element the condition of symmetrical stribution of current about the mid-point is fulfilled. We shall replace ch individual section by a dipole located at its mid-point. The resultant ctor then is

$$H \sin\left(\frac{n-1}{2}\beta\right) \cdot L \left(\sin\beta + \sin 2\beta + \cdots + \sin(n-1)\beta \right)$$

here N is the number of sections, h- the vector due to each dipole,

$$\beta = \frac{2\pi d}{\lambda} \cos\theta + \zeta$$

he angular phase difference between the component vectors, ζ - the hase displacement between the current in any two neighboring dipoles. v/ps

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When $\theta = \frac{\pi}{2}$, $\beta = \zeta$ and the phase of the current in the dipole at t
middle of the whole antenna and equivalent thereto is, with reference to
first element, given by

$$\frac{(n-1)}{2}\zeta$$

In view of the preceding, it is possible to obtain the phase
function of a system of antennas of this kind by replacing each individual
wire by a dipole located at its center and oscillating with phase

$$\Delta = \gamma + \frac{(n-1)}{2}\zeta \qquad (7)$$

where γ is the phase of the current in the first element of the individ
wire.

b) Let us consider a system of n vertical radiators each of
length $\frac{\lambda}{2}$ arranged in horizontal line. Let the distance between any t
radiators be $\frac{\lambda}{2}$. Let all radiators oscillate in the same phase.
Let us assume that this system is located at the center of a large sphere
(Fig. 1) and that the axes of all radiators are directed toward the pole o
and that the line which joins the centers of the radiators coincides with t
diameter NS_1 for $\alpha = \frac{\pi}{2}$. It is known that for every conductor of length
$\frac{\lambda}{2}$ the amplitude of the magnetic vector on the surface of the sphere is

$$A = \frac{2i}{\rho c_0} \qquad (8)$$ where i is the loop current, ρ the radius of t
sphere and c_0 the velocity of light. In the case of n equi-spaced radi
at the center of the sphere

$$H = n A \psi(\theta, \alpha)$$

If we integrate the pointing vector over the surface of the sphere we obta

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total power of radiation:

$$P = \frac{n^2 i^2}{\rho_0 \pi} \int_0^{\pi - 2\alpha} \int_0^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \varphi'(\beta, \alpha_1)\, d\alpha \cdot d\theta .$$

i is in absolute electrostatic units. In order to convert these units to the practical units it is necessary to multiply the right-hand side by ρ_0 and then P will be expressed in watts. The resistance of the whole system is obviously $R = \frac{P}{(ni)^2}$ While the power due to a single one is $\beta = \frac{P}{n}$ and its resistance (average value) $r = \frac{P}{n i^2}$ subsequent numerical values which follow are given for this latter quantity.

Now we wish to find the phase function. It is obvious that at point E_1 on the equator whose coordinates are

$$\alpha_1 = 0 \quad \text{and} \quad \theta = \frac{\pi}{2}$$

magnetic vectors add algebraically when this sphere is sufficiently large that the phase differences are zero. The mean square value of the resulting magnetic vector at this point is $H = nh$ where h is the value of the vector due to a single radiator. If one moves along the equator because of the variations of α_1, the resultant vector also varies for there arise phase differences between fields produced by the individual radiators. The phase difference between the vectors due to two neighboring radiators is

$$\beta = \frac{2\pi d}{\lambda} \sin\alpha_1 = \pi \sin\alpha_1$$

With the help of equation (8) we have

$$\frac{H}{h} = \frac{\sin\left(\frac{\pi n}{2}\sin\alpha_1\right)}{\sin\left(\frac{\pi}{2}\sin\alpha_1\right)} \qquad (9)$$

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This is the phase factor for the points on the equator. In order to determine the phase factor for any arbitrary point M on the sphere, it is necessary to find the equatorial coordinate of the arc of the small circle which passes through the point and which lies in a plane perpendicular to the axis M_1. The value so found must be substituted into equation 9. If M is projected on the equatorial plane (Fig. 5) it is found that $OM = \rho \sin\theta$. Where ρ is the radius of the sphere; moreover, as it is obvious from the drawing we have

$$\sin\alpha_1 = \sin\theta \cdot \sin\alpha \qquad (10)$$

By substituting from this relation into equation (9) we obtain the value of the desired function on the surface of the sphere

$$Y_L = \frac{\sin\left(\frac{\pi n}{\lambda}\sin\alpha \cdot \sin\theta\right)}{\sin\left(\frac{\pi}{\lambda}\sin\alpha \cdot \sin\theta\right)} \qquad (11)$$

The power radiated from the system in question is

$$P = \frac{60 i^2}{\pi}\int_0^{\pi}\int_0^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} y_2^2 \, d\alpha \, d\theta \qquad (12)$$

An approximate graphical calculation yields:

n	2	3	4	5
r	58	62	57	70 λ

When the number of antennas is large, the total radiation is concentrated within a narrow ring delimited by arcs of two small circles which are parallel to the main meridian plane. (Fig. 6).

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By regarding the surface of this ring as being approximately

linistical we may put $\sin\alpha = \alpha$ and obtain

$$H = \frac{2(n\,l)}{c_0 \rho} \frac{\cos\frac{\pi}{2}\cos\theta}{\sin\theta} \cdot \frac{\sin\frac{\pi n}{2}}{\frac{\pi}{2}\alpha} \qquad (15)$$

account of the smallness of θ the phase function does not depend upon

$$dP = 2\pi\rho^2 \frac{c_0 H^2}{4\pi} d\alpha \cdot d\theta$$

use, then one uses practical units one obtains

$$P = \frac{60 n^2 i^2}{\pi} \int_0^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta} d\theta \cdot 2 \int_0^{+\frac{2}{n}\pi} \frac{\sin^2\frac{\pi n\alpha}{2}}{\left(\frac{\pi n\alpha}{2}\right)^2} d\alpha \qquad (16)$$

e limits of the second integral are to be determined in the following manner: he border-line of the main ray corresponds to $\alpha = \frac{2}{n}$ for then the integrand asses through zero for the first time. The other rays are marked out by ones determined by $\alpha = \frac{4}{n}, \frac{6}{n}, \ldots$

since the energy of the side rays rapidly decreases with the order number of the ay one may consider only an arbitrary number of rays K and neglect the energy f the remaining rays. In so doing K/n remains small, for n may be chosen to e arbitrarily large. Let

$$\frac{\pi n\alpha}{2} = z$$

then

$$P = \frac{120 i^2 n}{\pi^2} \int_0^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta} d\theta \cdot 2 \int_0^{K\pi} \frac{\sin^2 z}{z^2} dz \qquad (18)$$

The first integral may be expressed as follows:

$$\int_0^{\pi} \sqrt{1-u^2}\,\cos\pi u\,du \qquad (19)$$ v/39

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This is Bessel function $J_{\frac{1}{2}}$ whose value may be obtained from tables *) (see footnote). Its value is approximately 1.4.

The second integral may be transformed into integral cosine with double limits, and when Z is large, it is approximately equal to $\frac{\pi}{2}$. Therefore

$$r = \sim 56\,\Omega$$

c.) Let us now consider an antenna of the same kind in which the phases in the neighboring vertical wires are 180° apart. These antennae produce a main ray in the direction of the base line. In order to obtain the maximum radiation when $\alpha = 0$ the base line must be directed at right angles to the axis SS_1. It may be shown that in this case the phase function

$$Y_3 = \frac{\sin\left[\frac{\pi n}{2}(1 - \cos\alpha \sin\theta)\right]}{\sin\left[\frac{\pi}{2}(1 - \cos\alpha \sin\theta)\right]} \qquad (17)$$

Accordingly the power will be

$$P = \frac{60 i^2}{\pi} \int_0^{\pi} \int_{-\pi}^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} Y_3^2 \, d\theta \, d\alpha \qquad (18)$$

An approximate, graphical calculation yields:

$n =$	2	3	4
r	88	95	100 Ω

When n is large expression (18) may be replaced by a simpler one. In the system under consideration the main ray, as well as the side rays, are delimited by cones the vertices of which are located at the center of the sphere while

*) E. Jahnke und F Emde, Funktionentafeln.

their axes coincide with the base line of the antennas. The traces of intersection of these cones with the sphere are circles. (Fig. V) In that portion of the sphere which is delimited by such a circle which corresponds to the number K say, the Pointing Vector may be taken to be constant and equal to

$$\Pi = \frac{(n i)^2}{c_0 \rho^2 \pi}$$

and $(\sin\alpha)$ may be replaced by α . If the whole surface is sub-divided into rings

$$dS = 2\pi \rho^2 \alpha \, d\alpha$$

we obtain

$$dP = \Pi \, dS \, Y_4^2$$

the phase function may be written as follows

$$Y_4 = \frac{\sin\left[\frac{\pi n}{2}(1-\cos\alpha)\right]}{\sin\left[\frac{\pi}{2}(1-\cos\alpha)\right]} = \frac{\sin^2 \frac{\pi n \alpha^2}{2}}{\left(\frac{\pi n \alpha^2}{4}\right)^2} = \frac{\sin^2 \frac{z}{2}}{z^2}$$

then

$$P = \frac{2 c_0 n i^2}{\pi} \int_0^{n\pi} \frac{\sin^2 \frac{z}{2}}{z^2} \, dz$$

For large values of K in accordance with the theorem

$$r \sim 120 \, \Omega$$

(b) Now we shall consider two more types of standard antennas composed of vertical radiators of length $\frac{\lambda}{2}$ and directed parallel to the same axis. In the antenna of the first kind all radiators vibrate in the same phase while in the antenna of the second kind the phases of neighboring radiators differ by 180^0. It is clear that in this vertical arrangement of antennas the foregoing questions in regard to the phase function still hold good. The difference consists only in that in this

V/...

case the zones of constant phase centers lie not in vertical but in horizontal planes which are parallel to the equatorial plane. For this reason the distribution of radiation depends not on the azimuth but on the polar distance. By analogy with the previous reasoning we obtain for "in-phase" antennas

$$P = 60\, i^2 \int_0^{\pi} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} \cdot \frac{\sin^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\left(\frac{\pi}{2}\cos\theta\right)} d\theta - A^2 \qquad (20)$$

by the series expansion

$$\frac{\sin^2(n\chi)}{\sin\chi} = \sin\chi + \sin 3\chi + \cdots + \sin(2n-1)\chi$$

then $\chi = \frac{\pi}{2}\cos\theta$ because of the relation $\sin\chi = \sqrt{1-\cos^2\chi}$

Integral (20) may be expressed in the following manner:

$$M = N_1 + N_2 + \cdots + N_n \qquad (21)$$

where $$N_n = A_n \int_0^{\pi} \frac{\cos^{2n}\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta} d\theta$$

let $\cos\theta = \chi$

$$N_n = \int_{-1}^{+1} \frac{\cos^{2n}\left(\frac{\pi}{2}\chi\right)}{1-\chi^2} d\chi = \int_{-1}^{+1} \frac{\cos^{2n}\left(\frac{\pi}{2}\chi\right)}{1+\chi} d\chi$$

Furthermore by putting $z = \frac{\pi}{2}(1+\chi)$ we obtain

$$N_n = \int_0^{\pi} \frac{\sin^{2n} z}{z}\, dz = \frac{(-1)^{n+1}}{2^{2n-2}} \left[\int_0^{n\pi} \frac{\sin^2 z}{2}\, dz - \right. \qquad (22)$$

$$- 2n \int_0^{(n-1)\pi} \frac{\sin^2 z}{2}\, dz + \frac{2n(2n-1)}{1\cdot 2} \int_0^{(n-2)\pi} \frac{\sin^2 z}{2}\, dz - \cdots \pm B \left. \int_0^{\pi} \frac{\sin^{2n} z}{2}\, dz \right]$$

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by introducing the abbreviation

$$\int_a^{a\pi} \frac{\sin^2 z}{z} dz = \int_0^{a\pi} \tag{25}$$

and expressing E_1 , E_2 , ... by means of S it is possible to transform the integral E in the following manner:

$$M = (-1)^{n-1} 2\cdot i^2 \left[\int_0^{n\pi} - 4 \int_0^{(n-1)\pi} + 8 \int_0^{(n-2)\pi} - \cdots \pm 4^{(n-1)} \int_0^{\pi} \right] \tag{26}$$

By applying Van der Pol's solution we obtain:

$$\int_0^{a\pi} = \frac{1}{2} \left[E + \log_e 2\pi a - Ci\, 2\pi a \right] \tag{27}$$

Where E is Euler's constant .577... and Ci is the integral cosine which does not differ greatly from zero for all values of the arc equal to

(n is an integral number).

From formula (26) we find the following numerical values

E	S	4	8
20	126	126.8	126.8

Then n is very large the value of P may be found in the following manner. The limit of the angle which includes the number K may be determined by means of relation

$$\cos\theta = \frac{2K}{N}$$

where the value of K may be taken to be as large as desirable. If at the same time $\frac{K}{N}$ is very small cos θ approaches zero and sin θ approaches unity. Equation (2) then assumes the following form

$$P = \frac{240 N i^2}{\pi} \int_0^{K\pi} \frac{\sin^2 z}{z^2} dz \tag{28}$$

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and, as before, it yields the resistance of a single antenna in the presence of a large number of antennae, namely,

$$r = 120\ \Omega$$

In case of antennae of the second kind (harmonic)

$$P = 60\, i^2 \int_0^{\pi} \frac{\cos^2\left(\frac{n}{2}\cos\theta\right)\sin^2\left[\frac{n\pi}{2}(1-\cos\theta)\right]}{\sin\theta\,\sin^2\left[\frac{\pi}{2}(1-\cos\theta)\right]}\, d\theta \qquad (27)$$

when n is even

$$P = 60\, i^2 \int_0^{\pi} \frac{\sin^2\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}\, d\theta \qquad (28a)$$

when n is odd

$$P = 60\, i^2 \int_0^{\pi} \frac{\cos^2\left(\frac{n\pi}{2}\cos\theta\right)}{\sin\theta}\, d\theta \qquad (28b)$$

With the aid of Van Der Pol's solution we obtain

$$P = 30\, n\, i^2 \left[E + \log_e 2\pi n - Ci(2\pi n)\right] \qquad (29)$$

Where Ci, as before, is the integral cosine, the value of which is not far from zero. The following table gives the value of the resistance for various values of n.

1	2	3	4	5	6	7	8
72.5	67	35.2	33.3	34.3	21.1	27.3	16.90

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c.) Certain more complicated combinations may be reduced to the discussed typical cases; thus, for example, a combination of stacked antennae with a horizontal base line, as well as "space systems", which consist of a number of radiators, may be so reduced. The rule for compounding the formula is the same and it may be expressed as follows:

$$P = \frac{60 i^2}{\pi} \int_0^{\pi} \int_0^{\pi} \frac{\cos^2\left(\frac{n}{2}\cos\theta\right)}{\sin\theta} \cdot y_1 y_2 y_3 \ldots \, dx \cdot d\theta \qquad (30)$$

II. Distribution of Radiation in Space.

The regions of darkness are distributed, as has already been said, along the arcs of small circles of the sphere which surrounds the antenna. These arcs satisfy the condition $Y_K = 0$ where Y_K is a phase factor occurring in expression (30). For single stack antennae the projections of these circles on the equatorial plane are straight lines aa, bb (Fig. 8). These straight lines are parallel to the projection of the main meridian. In the case of an in-phase system of radiators, the main ray is marked out by zones a. The space occupied by said ray may be obtained by rotating sector a_2Oa_2 around O.

In the case of a system with alternating phases (harmonic) the main ray is limited by zone b. The space occupied by this ray may be obtained by rotating sector b_1OB_1 around axis OB_1 and thus the shape of a cone. Here is apparent the noteworthy difference between the radiation distribution due to the two systems. This difference becomes apparent when the radiation distribution along the equatorial plane is compared with that along the arc of any small circle. The projections of the latter are indicated in Fig. 8 by dotted lines. It is easily seen that as the small circle approaches the

zenith the side rays successively diminish. In the region nearer the zenith there remains only the main ray which itself finally practically disappears at some definite angle of altitude in a given in-phase system. Conversely, in case of an antenna with alternating phases, as the altitude above the horizon increases the main ray disappears first and is followed by side rays in succession. In case of multi-stacked antennas the projections of the zones of zero radiation (darkness) are represented by concentric circles whose common center coincides with the center of the equatorial plane (Fig. 9). By combining the two types of radiators into a single system a space antenna is obtained which may have several stories. In this case the projections of regions of darkness on the equatorial plane have the appearance of a net (Fig. 10). The radiation of a system or this consists of a large number of individual rays of different intensities and shapes separated by mutually intersecting zones of darkness.

II. The Mirror.

a.) The action of an unlimited conducting mirror may be replaced by the action of the images of the real antennas. For radio frequency waves the surface of the earth is more like a surface of a scattering medium. The reflection depends upon the wave length, upon the angle of incidence of the ray and, very probably, on the amplitude of the electromagnetic field. In the first approximation one may regard the earth as a metallic mirror. This is confirmed by experiments in case of reflection of waves of order two meters from soils moistened with water of small salt content. In what follows the surface of the earth will be considered to be flat and possessing an absorption coefficient K. By the absorption coefficient will be meant the ratio of the

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absorbed to the incident energies.

Let us consider an antenna with vertical radiators located at the center of a large sphere, the equatorial plane of which coincides with the surface of the earth. Let us first determine the resulting magnetic vector H on the surface of the sphere which is due to vectors h and $h\sqrt{1-K}$ produced by the antenna itself and its image. In order to find the phase function φ the antennas will be replaced by dipoles. The phase difference between the component vectors at a point on the sphere is due, first of all, to phase difference ψ produced by the difference of travel of the rays $\psi = \frac{4\pi\ell}{\lambda}\cos\theta$. Here ℓ is the distance of the midpoint of the antenna from the surface of the mirror and θ is the polar coordinate of the point. Secondly, the phase difference depends upon the difference in current phases in the dipoles at the center of antennas which must be determined in accordance with formula (7). Because the phase of each such dipole with respect to the first element of the antenna is equal to $\Delta = \gamma_1 + \zeta\frac{(n-1)}{2}$ the phase difference

$\Delta_1 - \Delta_2 = \gamma_1 - \gamma_2$ where γ is the phase of the first element.

In cases of in-phase antennas (Fig. 11) it is clear that $\gamma_1 - \gamma_2 = 0$

In the case of an antenna with alternating phases (Fig. 12) we have

$$\gamma_1 - \gamma_2 = \pi_1 n-1$$

Accordingly, the root mean square value is

$$H^2 = \ell^2\left[2 - K + 2\sqrt{1-K}\cos\left(\gamma_1 - \gamma_2 + \frac{4\pi\ell}{\lambda}\cos\theta\right)\right] \quad (11)$$

The square of the phase function including the corrections due to the loss of energy at reflection is easily seen to be $\psi_1^2 = \frac{H^2}{h^2}$

When for a given antenna system, when it is removed to a considerable distance

from the earth, the radiated power is given by

$$P_1 = A\int_0^{2\pi}\int_0^{\pi} f^2(\alpha,\theta)\,d\alpha\,d\theta \qquad (32)$$

then the mirror action of the earth results in the following power

$$P_2 = A\int_0^{2\pi}\int_0^{\frac{\pi}{2}} f(\alpha,\theta)\,\psi_1^2\,d\alpha\,d\theta \qquad (33)$$

and the total power radiated by the antenna is

$$P_3 = \frac{P_2}{1-\frac{\kappa}{2}} \qquad (34)$$

In this fashion the antenna resistance in the presence of the earth may be found.

The presence of factor 42 in the integrand produces new zones of reduced radiation which lie in the planes of small circles defined by the following equation:

$$\cos\left[\frac{4\pi\ell}{\lambda}\cos\theta - \gamma_1 + \gamma_2\right] = -1 \qquad (35)$$

In order that complete darkness may be produced it is necessary that

$\kappa = 0$ The number of these zones increases with ℓ.

If K is put equal to zero and $\ell = \frac{\lambda n}{4}$

and if the phase function ψ_1 is introduced into the equation, for the alternating phase antenna, the formulas of Ballantine and Van der Pol are obtained in the following form

For even n

$$P = 60 i^2 \int_0^{\frac{\pi}{2}} \frac{[1-\cos(\pi n\cos\theta)]^2}{\sin\theta}\,d\theta, \qquad (36)$$

For odd n.

$$P = 60 i^2 \int_0^{\frac{\pi}{2}} \frac{[1+\cos(\pi n\cos\theta)]^2}{\sin\theta}\,d\theta$$

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b) Let us consider an antenna system with vertical radiators located at the center of the usual large sphere and let there be an infinite periodic mirror parallel to the axis of the oscillators and to their base line SS_1. In the equatorial plane on the surface of this sphere the phase displacement between the vectors due to the antenna and those due to its image is

$$\varphi = +\frac{4\pi l}{\lambda}\cos\alpha + \gamma_1 - \gamma_2$$

where l is the distance of the mirror surface from the geometric mid-point of the antenna, and $\gamma_1 \quad \gamma_2 = \pi$ (Figs. 13 and 14).

If this expression is extended to apply the complete sphere the phase function is found to have the following form

$$V_2^2 = \left[2 - \kappa - 2\sqrt{1-\kappa}\cos\frac{4\pi l}{\lambda}\cos\alpha\sin\theta\right] \quad (27)$$

The intersections of zones of darkness with the equatorial circle are determined by the condition

$$\cos\frac{4\pi l}{\lambda}\cos\alpha = \pm 1 \quad (28)$$

The planes of these zones of darkness are parallel to the plane of the mirror and in the case in question are at right angles to the main meridian circle.

c) The mirror action of the earth in the case of an inclined antenna is of great interest. V/77

The analytical study of this case is very complicated and we shall limit ourselves to the following observations. The law $h_0 = f(\psi, \theta)$ for the amplitude of the magnetic vector which is produced on the sphere by the antenna is assumed to be known when the axis of the sphere is parallel to the axis of the radiator. In case of a sphere, the polar axis of which makes an angle ε with the axis of the radiator, we have $h_0 = f(\beta, \Delta)$ where β and Δ are the new variables, connected with the old variables by known relations obtainable from the rotation of the polar axis. When the plane of the mirror coincides with the equatorial plane of the new coordinate system the axis of the radiators in the image make angle $\pi - \varepsilon$ with the new polar axis.

The amplitude of the magnetic vector which is produced by the image is expressed as follows:

$$h_0' = \sqrt{1-\kappa}\, f[(\pi - \Delta), \beta]$$

that is, it differs from the corresponding expression for the antenna itself.

When the phases of the two vectors coincide, the amplitude of the resultant vector is a geometrical sum of the components with an angle ε included between them. In fact, such a coincidence of phases occurs only at certain points on the sphere so that, in general, there exists a phase difference which is due to the difference in path. In such cases it is possible to obtain the resultant vector in the following

v/so manner

Let $h_0 \sin(\omega t)$ (Fig. 18) be the vector due to the antenna and let $h_0' \sin(\omega t + \varphi)$ be that due to the image; both at a given point on the sphere. Suppose that the directions of the two vectors make angle ζ with each other. Let the axis ox of the rectangular coordinates coincide with the directions of h_0 then the projections of the resultant vector H on the x and y axes are

$$H_x \sin z = h_0 \sin \omega t + h_0' \sin(\omega t + \varphi' \cos \zeta \quad (39)$$

$$H_y \sin z_1 = h_0' \sin(\omega t + \varphi) \sin \zeta \quad (40)$$

Since

$$H_x^2 = h_0^2 + (h_0' \cos \zeta)^2 + (h_0' \cos \zeta)^2 + 2 h_0 h_0' \cos \zeta \cos \varphi \quad (41)$$

$$H_y^2 = (h_0' \sin \zeta)^2 \quad (42)$$

Since H_x and H_y are at right angles to each other the Pointing Vectors for each component may be calculated separately and the sum of these will represent the resultant vector. The cooperation of H_x and H_y produces a rotating field when ζ is not equal to $\kappa\pi$ and $\varphi \neq \kappa\pi$ (κ is the whole number).

In this case the phase function cannot be written out for h_0 and h_0^1 vary in accordance with two different laws. The distribution of regions of darkness due to the antenna and its image depend on whether the antennae alone or their base lines as well are inclined. v/s1

In the latter case, the interference phenomena acquire even more complicated character and the coincidence of zones of darkness of the antennas and of those of the mirror is increased In this case, there exists only a diminution of radiation at the intersection of zones due to the antennas and the mirror. In that manner the inclination of the antennas with respect to the mirror does away with interference bands and consequently acts in a favorable manner in regard to the phenomena of fading.

Fig. 18 represents the projection of the radiation picture of an in-phase system with elevated horizontal Lecher wires. The plane of the system is inclined. The antenna and its image have common zones of darkness. The main Ray is inclined to the earth at the same angle as the inclination of the antennas. By means of dotted circles with the center at the pole, are represented the zones which correspond to the zones of darkness produced by the interference of radiation from the antenna and its image. In this case, however, there are no zones of darkness but regions in which the magnetic vectors from the antennas and its image meet in opposite phase. This does not bring about darkness since the laws of variation will differ for the two vectors and a space angle exists between them.

Fig. 19 relates to the same antenna with an inclined Lecher system. The radiators are arranged in a plane perpendicular to the earth. On the sphere are two independent mutually intersecting systems of zones of darkness. The full lines indicating the zones due to the antennas while the dotted lines indicate the zones due to the image. A complete darkness can occur only at points at which both systems coincide. A similar

v/sr

terference picture occurs in case of an inclined wire with alternating

rent.

d) A tuned mirror may be excited or energized by means of special

upling with the antenna. In case then excitation is produced by driving,

is possible to vary the amplitude and the phase of the mirror in any manner

atever.

Let a vertical radiator of length $\lambda/2$ be placed in the center

the large sphere and let there be at a distance l and parallel to it a

rror β of the same length. The relation of the current in the mirror

that in the radiator is given by

$$\lambda = F(l)$$

e displacement of phase between the magnetic vectors A and B in the

quitorial plane is equal to the sum of the following quantities:

1. The lens of phase along the path A-B, that is

$$\frac{2\pi l}{\lambda}$$

2. The phase displacement produced by the difference in

ase (ι) between the fields which arrive at the mirror and which are pro-

ced by the mirror itself.

3. The phase difference which is due to the difference in

th

$$\frac{2\pi l}{\lambda} \cos \alpha$$

The first two terms have the same values for all points on the

here, the last may be given for different points on the surface in the

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following manner:

$$\frac{2\pi\ell}{\lambda}\cos\alpha\sin\theta$$

If the mean square value of the resulting vector on the sphere is (E) and the components are h and nh then

$$\psi_3^2 = \frac{H^2}{\ell^2} = 1 + N^2 + 2N\cos\left[\pi + \frac{2\pi\ell}{\lambda}(1+\sin\theta\cos\alpha)\right] \quad (42)$$

The value of ψ_3^2 varies in accordance with the argument of the cosine and remains between the limits. $(1+N)^2$ and $(1-N)^2$. When $N=1$ the maximum value of $\psi^2 = 4$ and the minimum value is zero. When N is approximately unity and (π) is near one finds for the equatorial plane the following. When the mirror is close to the antenna ($\ell = 0$) $\psi_3^2 = 0$ for every value of azimuth. When $\ell = \frac{\lambda}{4}$; then $\psi_3^2 = 4$ for $\alpha = \frac{\pi}{2}$ and $\psi_3^2 = 0$ for $\alpha = -\frac{\pi}{2}$

The radiation directed toward the antenna. When (ℓ) increases still further the ray divides itself into two parts which spread more and more on opposite sides. In the case when $\frac{\ell}{\lambda} = \frac{1}{3}$ the radiation diagram has a butterfly-like appearance and the two larger wings are directed towards the antenna. At the maximum when $\alpha = \frac{\pi}{4}$ and $\frac{3}{4}\pi$ $\psi_3^2 = 4$ When $\rho = \frac{\lambda}{2}$, $\psi_3^2 = 4$ and the radiation is directed at right angles to the line joining the antenna and its image. When the mirror is excited by induction from the antenna $N<1$ and N increases as the mirror approaches the antenna. From experience v/c

it has been found that the best direction of the ray is obtained when the $l < \frac{\lambda}{4}$.

It has been shown by W. W. Tatarinow that the best distance is $l = .20\lambda$.

When there is no forced excitation the phase function may be applied to complicated antennae only when the distance between the radiator and its mirror is considerably smaller than the distance to the nearest neighboring radiator. In this case the mirror may be assumed to be coupled only to one of the radiators.

When the mirror system is at distance $.20\lambda$ this condition is approximately fulfilled.

c) The resistance of an antenna in the presence of a mirror may be determined by obtaining the corresponding integral in which the integrand is multiplied by the phase function of the mirror. For example, in the case of a long vertical conductor with alternating phases the power is obtained in accordance with the equation (34)

$$P_3 = \frac{P_2}{1 - \frac{\lambda}{2}}$$

where P_2 is the reflected power. In accordance with equations (28) and (31) this power may be expressed in the following manner:

$$P_2 = 60 i^2 \int_0^{\frac{\pi}{2}} \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right) \sin^2\left[\frac{\pi}{2}(1-\cos\theta)\right]\left[2 - K + (-1)^{n+1} 2\sqrt{1-K}\cos\left(\frac{\pi l}{\lambda}\cos\theta\right)\right]}{\sin\theta \cdot \sin^2\left[\frac{\pi}{2}(1-\cos\theta)\right]} d\theta \quad (44)$$

N/53

The calculation of this integral yield the following

$$P_R = P_1 + (-1)^{n+1} \cdot 15\, i^2 \frac{\sqrt{1-\frac{1}{K}}}{1-\frac{1}{K}} \left[\sin(p\pi) \left[2\,Si(2p\pi) - \right.\right. \tag{45}$$

$$\left. - Si\{2\pi(p-n)\} - Si\{2\pi(p+n)\} \right] - \cos(p\pi) \left[2 \log(2\pi p) - \right.$$

$$\left. - 2Ci(2\pi p) - \log(2\pi(p-n)) - \log(2\pi(p+n)) + \right.$$

$$\left. + Ci(2\pi(p+n)) + Ci(2\pi(p-n)) \right] \Big]$$

where P_R is the radiated power in the absence of the mirror, and is determinable by equation (39). K is the absorption coefficient and n is the number of half-waves in the conductor, p is the distance of the mid-point of the conductor from the mirror in terms of quarter wave-lengths. Si the integral Sine; Ci the integral cosine, and Lg the natural logarithm.

When $p = \frac{4s}{\lambda}$ is a whole number, the first term in the brackets is equal to zero because $\sin p\pi = 0$

in the second term all the integral cosines will be approximately zero with the exception of the case when $p = n$

then

$$Ci(p-n) - \log(p-n) = E = .577 \tag{46}$$

When P is a whole number the shortest distance between the antenna and its image is a whole number of half wave lengths. When $2P$ is a whole odd number

$$\cos(p\pi) = 0$$

and consequently there remains only the first term in the square brackets. This corresponds to the case where the nearest point on the antennae is an integral number of quarter wave lengths from the image. In Figs. 18 and 19

are shown curves which were constructed in accordance with formula (45) for the case when the earth is regarded as having K = 0. The ordinates represent the increase in the radiation resistance of a half-wave length due to the influence of the earth. Through similar substitutions into equation (2) and calculations of therein contained integrals the following expressions are found for a system of in-phase vertical conductors:

$$P_3 = P_1 + 15 i^2 \frac{\sqrt{1-K}}{1-\xi} (-1)^{n+1} \left[S_0^{n\pi} - 4 S_0^{(n-1)\pi} + 8 S_0^{(n-2)\pi} - \right.$$

$$\left. - 12 S_0^{(n-3)\pi} + \quad \pm (n-1) 4 S_0^{\pi} \right] \qquad (47)$$

Here the abbreviations $S_0^{a\pi}$ is given by the following formula:

$$S_0^{a\pi} = \sin(p\pi) \left[2 \mathrm{Si}(2p\pi) - \mathrm{Si}(2\pi(p-a)) - \mathrm{Si}(2\pi(p+a)) \right] -$$

$$- \cos(p\pi) \left[2 \lg(2\pi p) - \lg 2\pi(p-a) - \lg(2\pi(p+a)) \right.$$

$$\left. + 2 \mathrm{Ci}(2\pi p) - \mathrm{Ci}(2\pi(p+a)) - \mathrm{Ci}(2\pi(p-a)) \right]$$

Here the letters have the same meaning as in equation (45).

Calculations may be carried through by successive substitutions of values of $S_0^{a\pi}$ for $a = n, n-1, n-2,$

into equation 47. When $p = \frac{4l}{\lambda}$ is a while number,

the first term in (45) is equal to zero and all integral cosines in the second term are nearly zero with the exception of the case $a = p$ when

$$\mathrm{Ci}(2\pi(p-a)) - \lg(2\pi(p-a)) = b = .577 \quad \text{V/57}$$

When N is an odd number, the second term is equal to zero. An investigation of equation (45) and (49) shows that the mirror near an antenna produces a considerable effect on the resistance of the antenna. Depending upon the distance between the antenna and the mirror, the radiator may bring about either an increase or a decrease of resistance.

When the lower end of a vertical conductor is located near the soil of high conductivity, a very small displacement of the conductor produces large changes in resistance.

f). In an important practical case when the mirror is located behind a flat in-phase directional antenna from which the radiation is directed to one side, the calculation of resistance is greatly simplified if it is assumed that the mirror does not influence the distribution of energy in the ray but merely rotates a half of it 180°. This, in the first approximation, is allowable only when the number of radiators is not too small.

Then in the previously derived formula (45)

$$4_3^2 = 1 + N^2 + 2N \cos\left[\zeta + \frac{2\pi\ell}{\lambda}(1 - \sin\theta \cos\alpha)\right] \qquad (45)$$

one may put $\sin\theta \cos\alpha = \cos\alpha_1$, α_1 equal to unity, since α_1 is small in the equatorial plane. Thus we have

$$4_4^2 = 1 + N^2 + 2N \cos\left(\zeta + \frac{4\pi\ell}{\lambda}\right) \qquad (49)$$

and consequently

$$\Gamma_3 - \frac{2P_3}{1+N^2} = \frac{2P_1}{1+N^2}\left[1 + N^2 + 2N \cos\left(\zeta + \frac{4\pi\ell}{\lambda}\right)\right] \qquad (50)$$

Formulas (46), (47) and (50) may be used for experimental determinations of the absorption co-efficients.

"Nizhni-Novgorod, Radiolaboratorium, April 20, 1926."

(Received June 11, 1926). V/51

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DEFENDANT'S EXHIBIT W

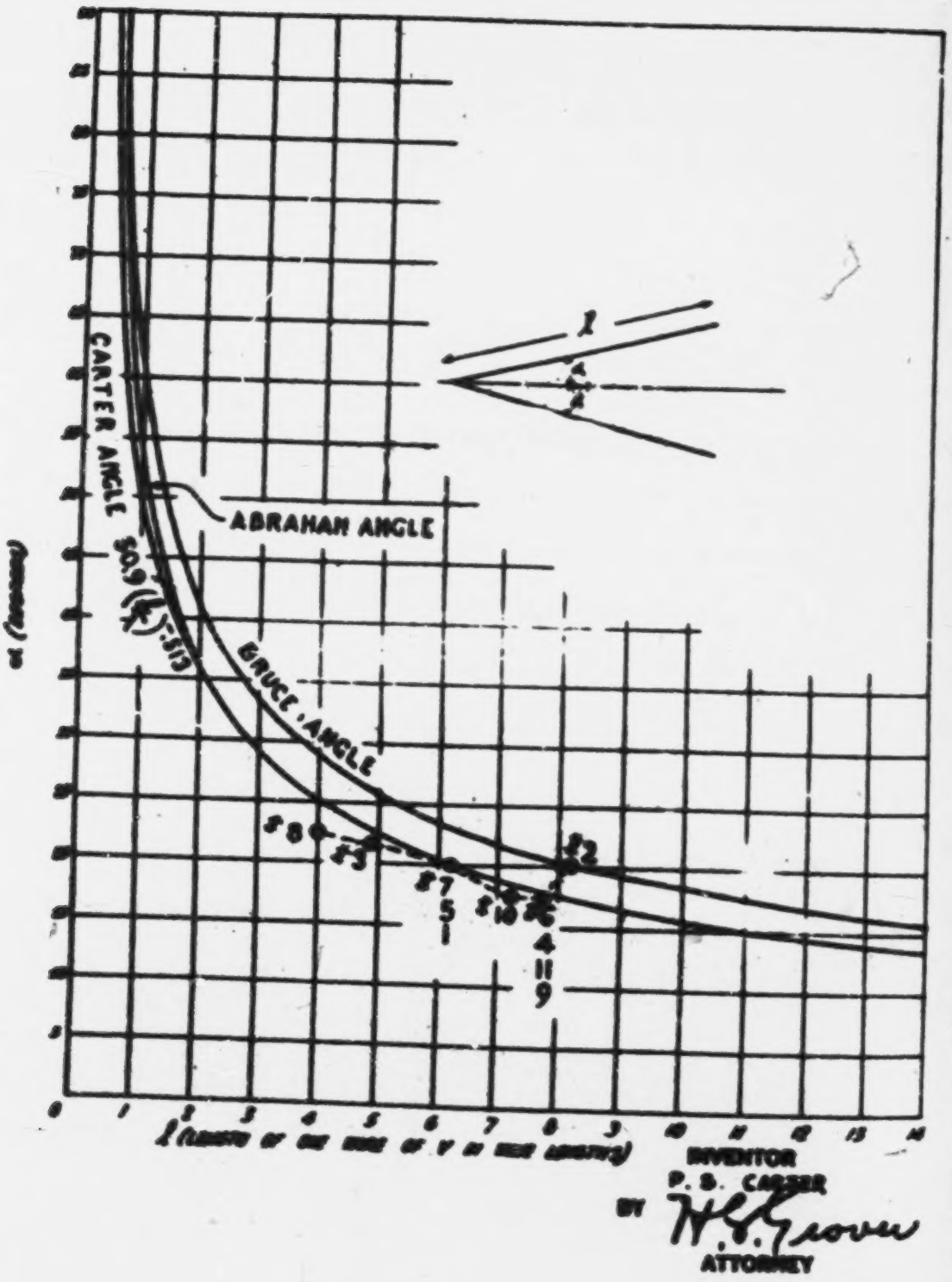
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Sept. 18, 1934. P. S. CARTER 1,974,387

ANTENNA

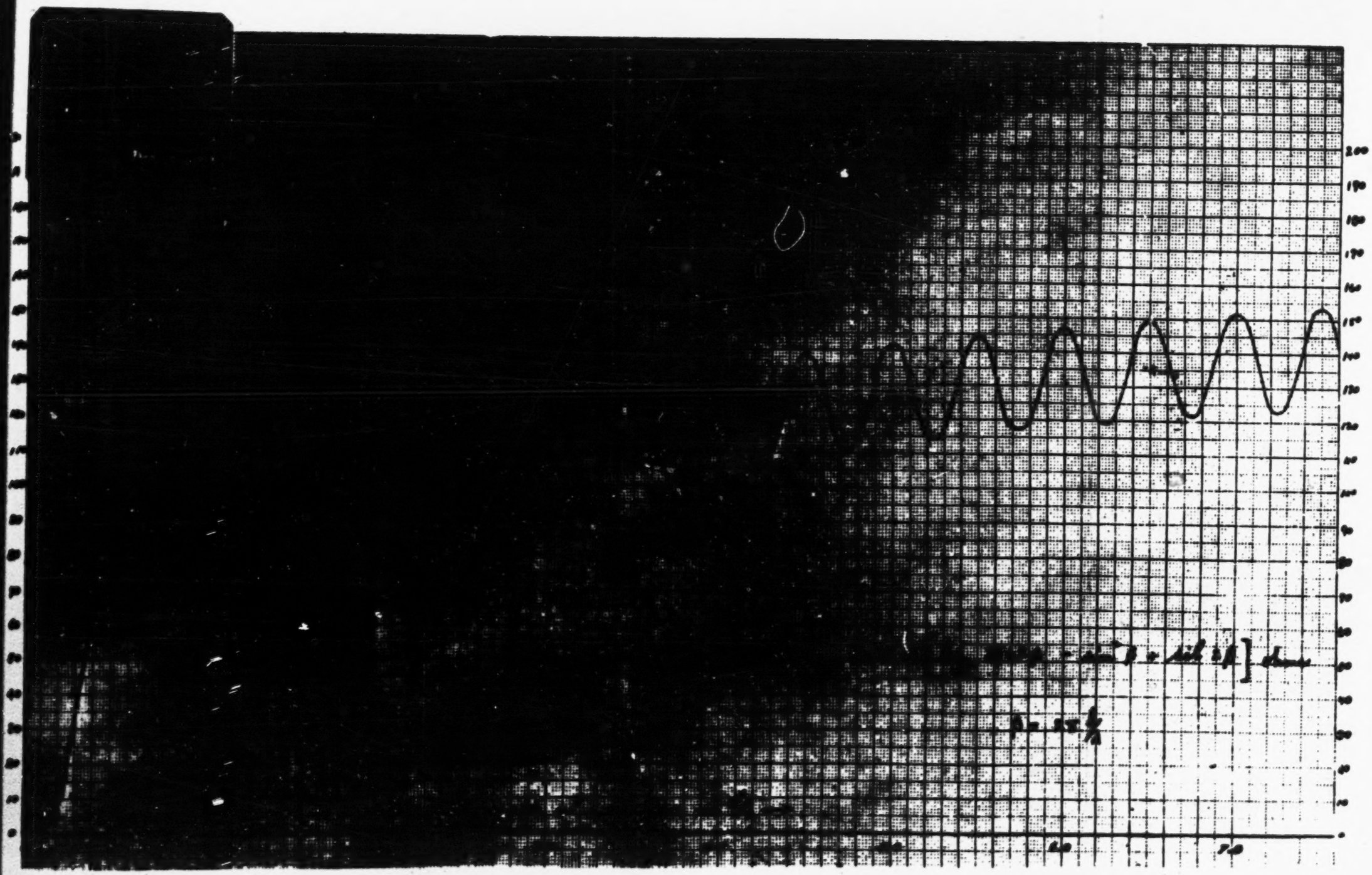
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Fig. 12



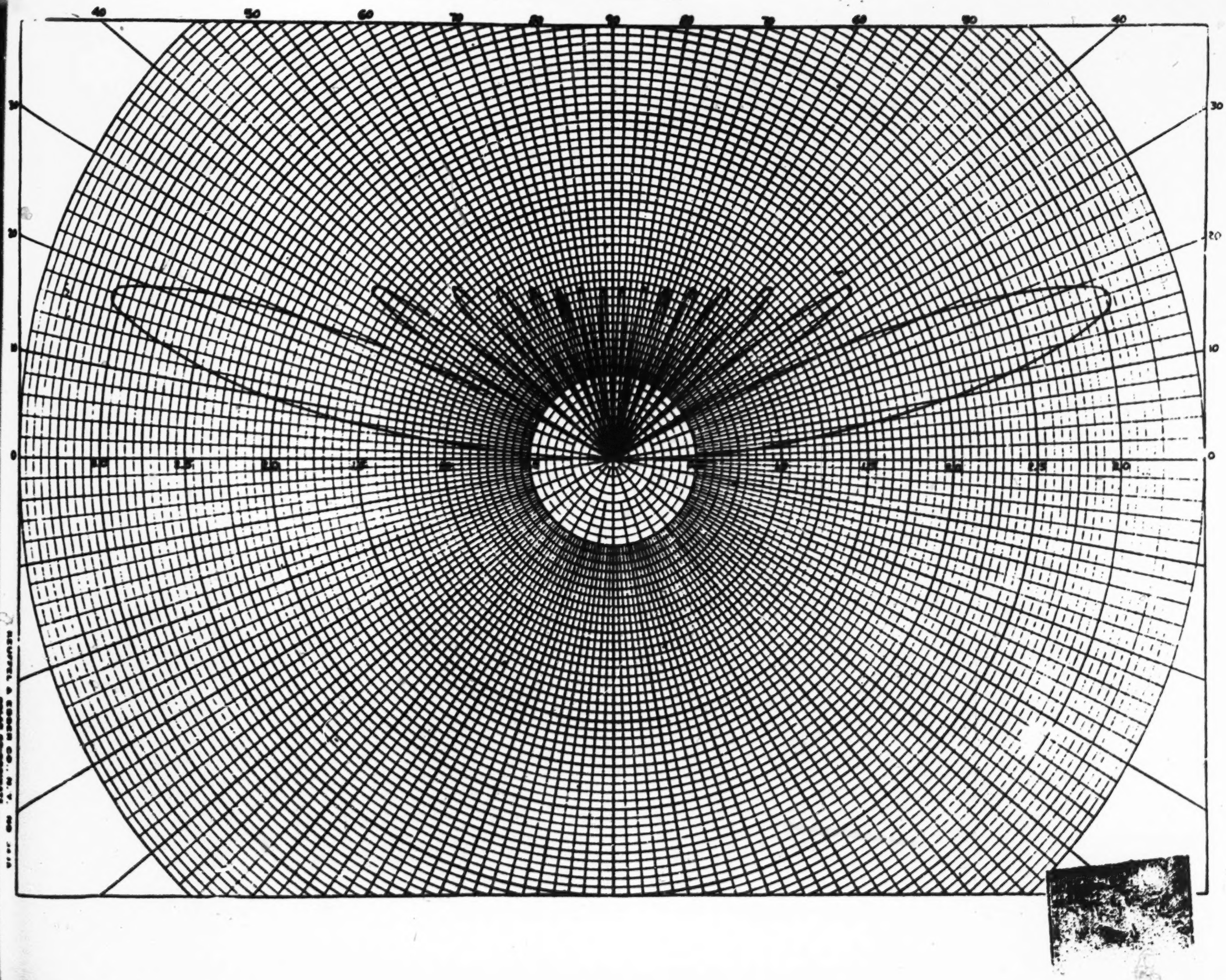
DEFENDANT'S EXHIBIT X

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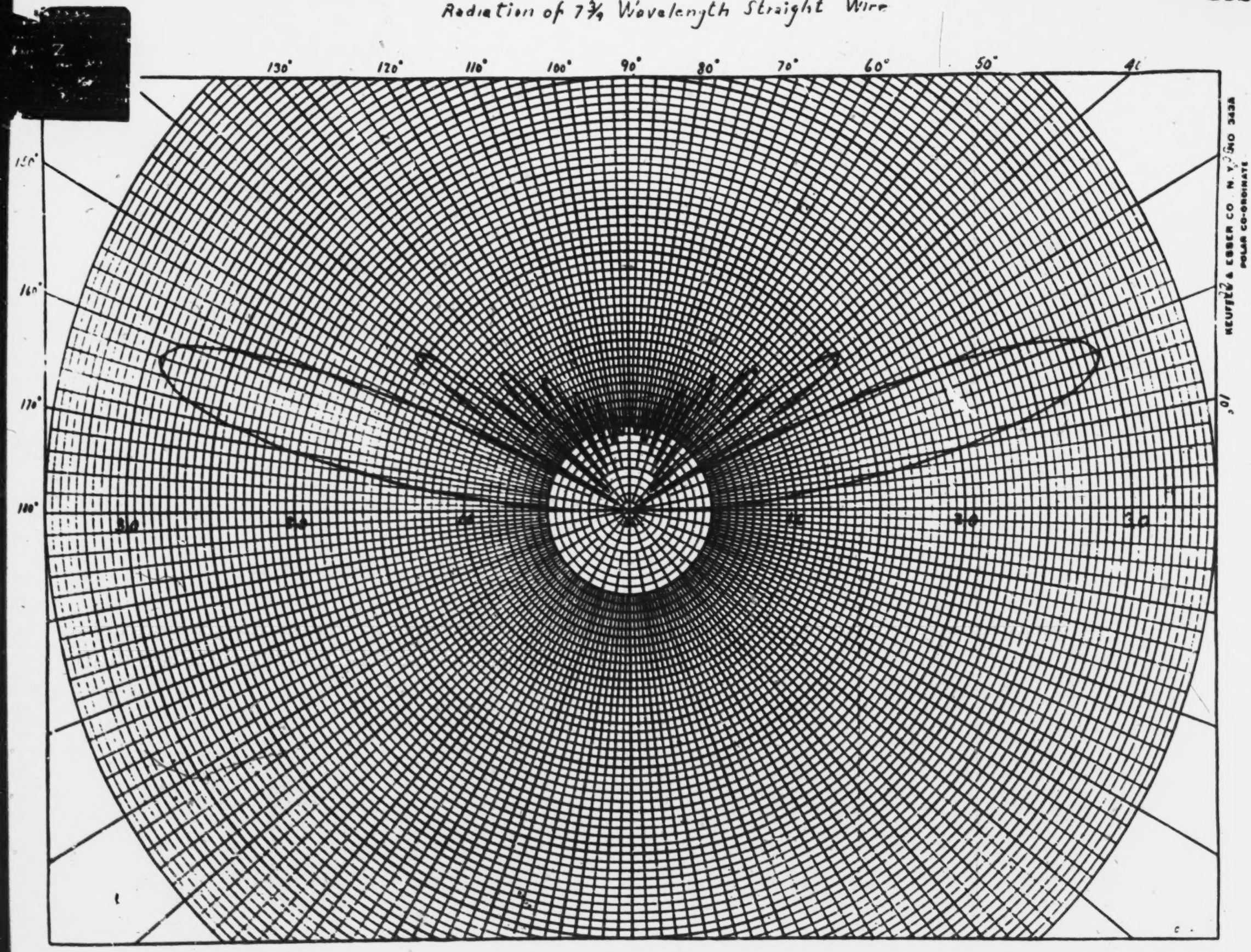
DEFENDANT'S EXHIBIT Y 1025

RADIATION OF 6 WAVELENGTH STRAIGHT WIRE



DEFENDANT'S EXHIBIT Z
1026

Radiation of 7¾ Wavelength Straight Wire



DEFENDANT'S EXHIBIT AA

TRANSLATION.

FRENCH PATENT NO. 596,737

JOSEPH ARMAGOD

SYSTEM OF AERIALS FOR THE TRANSMISSION OF SHORT WAVE WIRELESS TELEGRAPH SIGNALS.

Application filed July 11, 1924; patent issued August 14, 1925; published October 30, 1925.
(Patent whose issuance has been postponed pursuant to Article 11, paragraph 7 of the Law of July 5, 1844, amended by the Law of April 7, 1902.)

The present invention is based on the following experimental data:

It is known that an excellent sending antenna for medium or long waves may be constituted by a horizontal network of wires which are suspended from poles which are as high as possible. This will form the aerial proper and is connected through a suitable down-lead with one pole of the high frequency source which is provided on the ground. The other pole of this source is connected with a second horizontal network provided below the first at a slight distance above the ground, and forms what is called the counterpoise or screen. The fundamental wave length of such system is generally lower than the transmission wave length.

A similar arrangement may be provided for the emission of short waves and, in that case, the antenna thus constituted may be operated at the harmonics. However, in accordance with the arrangements forming the object of the present invention, it is important that the high poles be retained if it is desired that the antenna function in accordance with its fundamental wave. As a matter of fact, calculations and experiment show that with short waves the

higher the elevation of the counterpoise above the ground, the greater the advantages that may be derived therefrom. This consideration will lead one to the arrangement shown in Fig. 1 to exemplify the invention.

The poles 1-1 support the horizontal network 2 as high as possible. Under the network 2 is provided at 3, the counterpoise above referred to, insulators 4 being inserted in the suspension cables. In accordance with one of the characteristics of the invention, the height of 3 above ground 8 may be greater than the vertical distance between 2 and 3. It should be understood, of course, that, as well known, the screen 3 may cover a larger surface than the network. The feeder 5 of the network may be arranged in many ways, and particularly it may comprise either a single wire or a plurality of parallel wires. Furthermore, the portion of the down-lead 5 which is below the counterpoise 3 may be arranged in a different manner. It may constitute, with the conductor 6, which connects the counterpoise with the high frequency source M, F, a real double wire energy transmission line which has suitable characteristics, etc.

Fig. 2 exemplifies another solution in which relatively high poles 1 are used. The oscillator proper consists of a wire (or system of wires) 9 excited in any suitable manner from a high frequency source (not shown). In order to obtain a directional effect a series of vertical wires 10 forming a mirror are arranged in the well known manner along a parabolic base. These wires constitute a corresponding number of oscillators which are inductively excited and which are preferably tuned to the local oscillator 9. The latter may, as well known, be eliminated, provided that the oscillators 10

AA/

so respectively fed with currents which are suitably phased with respect to one another, etc.

Obviously, numerous other variants are possible. Particularly the two networks 2 and 3 of Fig. 1 may be arranged vertically or even inclined not only with respect to the ground, but also with respect to one another so as to obtain directional effects either in the horizontal plane, or in the vertical plane, or in both planes. Furthermore, as well known, the antenna may in all cases be, if necessary, excited at its harmonics.

Finally, the high frequency source itself may be arranged at a great height above the ground, e.g., at an intermediate platform on one of the poles. This arrangement would be particularly suitable for triode type generators, the current supply of the triodes being provided on the ground and connected with the high frequency apparatus through suitable cables.

R É S U M É

Antenna system for emitting short wave wireless telegraph signals, characterised by the provision of the oscillator at a relatively high point above the ground.

1030

N° 596.737 M. Bothmond Pl. unique

Fig. 1

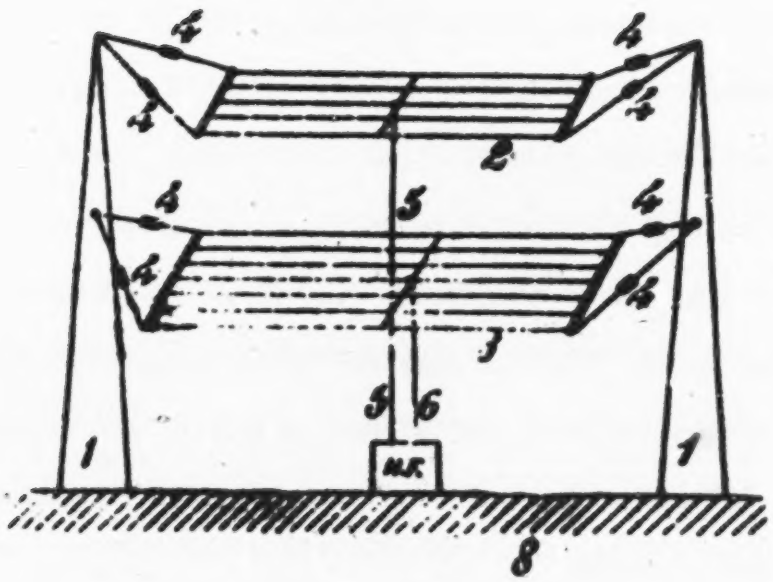
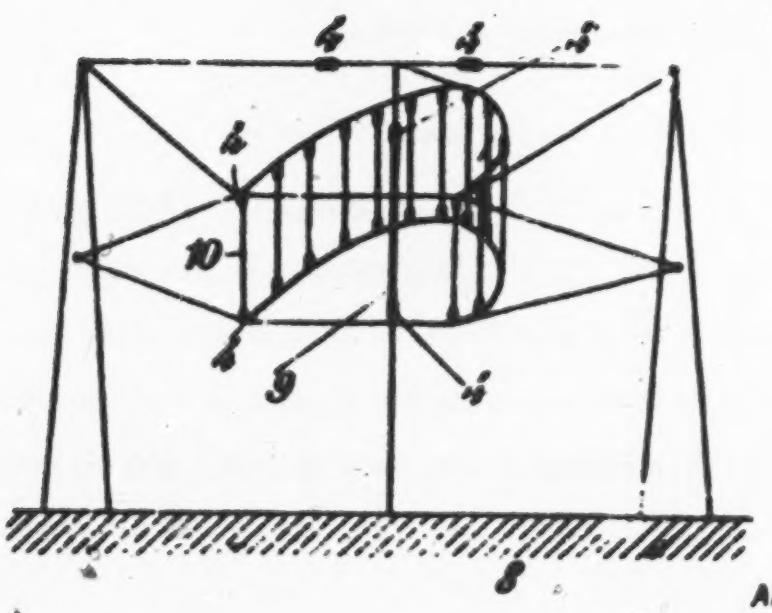


Fig. 2



AA/4

TRANSLATION -

FRENCH PATENT No. 625,898

JOSEPH ESTEVEZ

ANTENNA ARRANGEMENT FOR SHORT WAVES

Application filed March 9, 1926; issued April 25, 1927; published August 6, 1927.

The object of the present invention is an antenna arrangement which is particularly advantageous in communicating by means of short waves.

Better radiation output is obtained by suppressing losses in that portion of the antenna which is adjacent the station. Mechanical means permit that if required my antenna system may be used for waves of different lengths.

The invention will be better understood with reference to the enclosed drawing and the corresponding description which exemplify without limiting it one elementary embodiment of the invention.

The antenna consists of the conductors A, B, C, grounded at a. This antenna is excited by means of a high frequency current generator in any well known manner, e.g., by means of magnetic coupling with an inductance D connected in series with the antenna.

The portion A,B of the antenna included in the station or located in its immediate neighborhood is, in accordance with the present invention, provided with a screen E.F which may be a simple conductor identical with the portion A,B which we are considering, arranged parallel and sufficiently near thereto. In order completely to simulate said portion the screen E.F may comprise an inductance G, the inductances G and D being adjustable if desired. The screen E.F is connected to ground at E.

The portion B,C of the antenna may form an angle i of any value from 0 to 90° with the horizontal. The antenna is attached at C to an insulator H which

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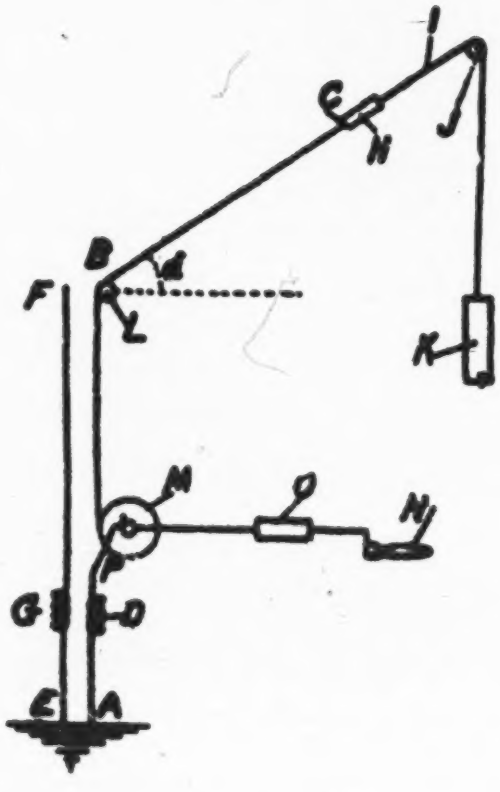
in turn is attached to a tensioning rope I. In order to obtain the greatest radiation efficiency for the antenna the length of B,C should preferably be equal to a whole number of half wave lengths. If the installation must operate on a plurality of different wave lengths then, in accordance with the present invention, the length of the portion B,C is made adjustable to the desired length, e.g., in the following manner:

The tensioning rope I passes over a pulley J and carries at its free end a counter-weight K which keeps it tensioned. The antenna conductor passes over a pulley L at B and its lower end is wound on a drum M which may be rotated by means of a handle N through an insulating sleeve O, or by any other equivalent arrangement. It will be understood that the continuity of the electric antenna circuit is insured by the provision of a system of movable connections, e.g., a wiper arrangement P which engages a ring carried by the drum, the wiper P being connected with the inductance D.

It should be noted that the invention may be subjected to many variations or modifications as far as the details are concerned; a plurality of antenna arrangements of the same type may be combined at the same station and suitably oriented with respect to one another in order to obtain directional effects or to make possible multiplex operation; the antenna and its screen may be interconnected at the points E and A without necessarily grounding these points; the inductances S and D will generally be coupled, care being taken suitably to direct the turns thereof, etc.

ABSTRACT

Antenna arrangement particularly applicable to short waves characterized in that radiation of the portion of the antenna which is near the station is neutralized by means of a screen; in that the radiating portion is inclined at any suitable angle with respect to the horizon and has a length equal to a whole number of half waves; and in that preferably this length is adjustable at will by means of a suitable mechanism.


I
C
H
J
B
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F
L
K
M
O
N
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E
A

[fols. 1035-1038] DEFENDANT'S EXHIBIT AA

831

No. 763,345. PATENTED JUNE 21, 1904.

F. BRAUN.

MEANS FOR TUNING AND ADJUSTING ELECTRIC CIRCUITS.

APPLICATION FILED AUG. 8, 1901.

NO MODEL. 3 SHEETS—SHEET 1.

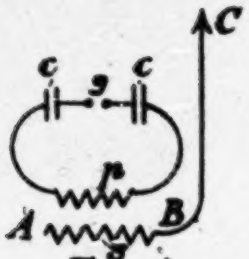


Fig. 1.

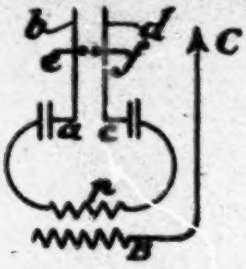


Fig. 2.

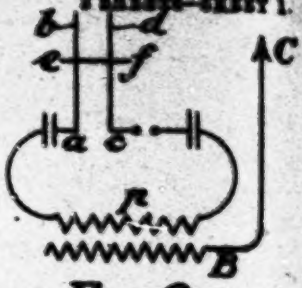


Fig. 3.



Fig. 4.

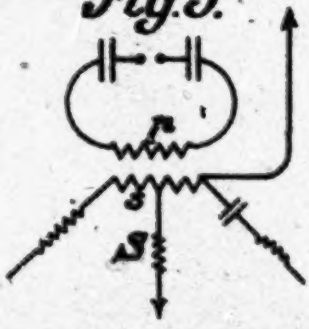


Fig. 5.



Fig. 6.

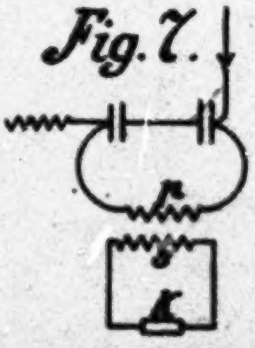


Fig. 7.



Fig. 8.



Fig. 9.

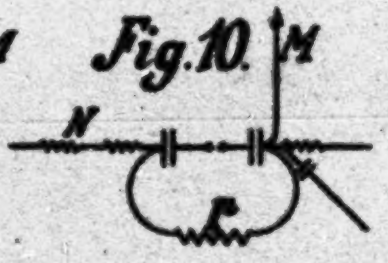


Fig. 10.



Fig. 11.

Witnesses:
[illegible]

Inventor
Ferdinand Braun
by Philipp Sawyer Rice & Kennedy
Attys.

832

No. 763,345. PATENTED JUNE 21, 1904.

F. BRAUN.

MEANS FOR TUNING AND ADJUSTING ELECTRIC CIRCUITS.

APPLICATION FILED AUG. 6, 1901.

NO MODEL. 2 SHEETS—SHEET 2.

Fig. 12.

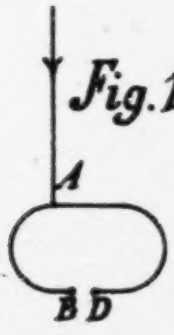


Fig. 13.

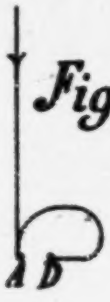


Fig. 14.



Fig. 15

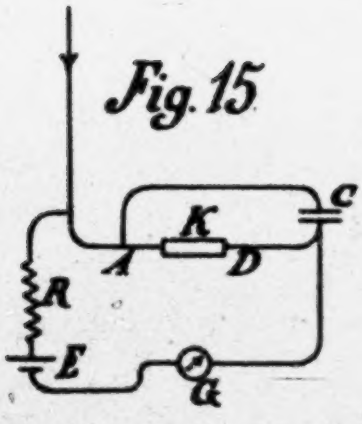


Fig. 16.

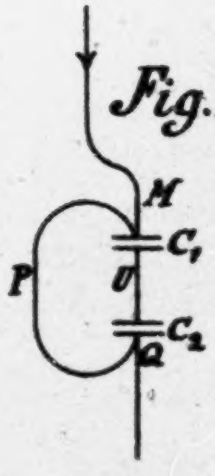


Fig. 17.

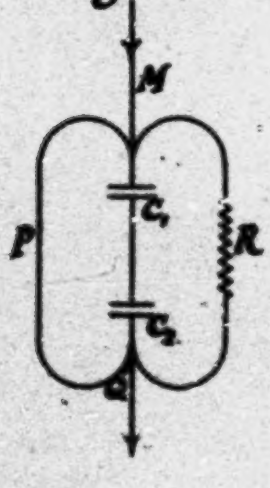


Fig. 18.

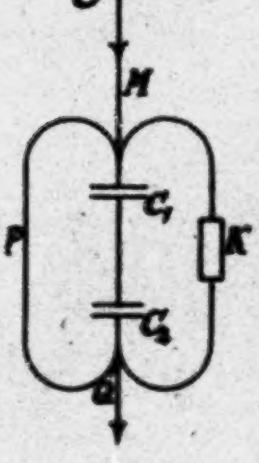
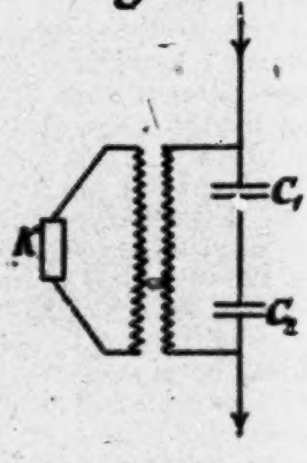


Fig. 19.



Witnesses:
T. Hyslop
M. F. Kennedy.

Inventor
Ferdinand Braun
by Philipp Sawyer Rice & Kennedy
Attys

No. 763,345. Patented June 21, 1904.

UNITED STATES PATENT OFFICE.

FERDINAND BRAUN, OF STRASBURG, GERMANY.

MEANS FOR TUNING AND ADJUSTING ELECTRIC CIRCUITS.

SPECIFICATION forming part of Letters Patent No. 763,345, dated June 21, 1904.

Application filed August 5, 1901. Serial No. 71,009. (No model.)

To all whom it may concern:

Be it known that I, FERDINAND BRAUN, a subject of the Emperor of Germany, and a resident of Strasburg, Alsace, German Empire, have invented certain new and useful Improvements in Means for Tuning and Adjusting Electric Circuits; and I do hereby declare that the following is a full, clear, and exact description of my invention, which will enable others skilled in the art to which it appertains to make and use the same.

It is known that wireless telegraphy may be made more effective by tuning the electric primary and secondary circuits of the sending and receiving instruments.

The object of the present invention is to improve such tuning.

In accordance with the invention the tuning may be accomplished by adding or inserting certain pieces or coils of wire, the length of which is determined by calculation or experiment.

Apparatus for practicing the invention is illustrated diagrammatically in the accompanying drawings, in which—

Figure 1 shows connections such as are now used for transforming electricity in the transmitter for wireless telegraphy. Figs. 2, 3, 4, and 5 illustrate different ways of modifying such apparatus for the purpose of practicing my invention. Figs. 6, 7, and 8 show the application of the invention to a wireless-telegraph receiver. Figs. 9, 10, and 11 illustrate other applications of the invention to a transmitter. Figs. 12, 13, and 14 illustrate apparatus for practicing the invention by the use of resonators. Fig. 15 shows more fully the electrical connections for a receiver; and Figs. 16, 17, 18, and 19 show other applications of the invention, which will be referred to.

In Fig. 1, which indicates a known form of wireless-telegraphy transmitter, the primary circuit includes the spark-gap *g*, the condenser *a*, and the primary coil *p* of the transformer. The secondary coil is represented by *s*, and BC is the transmitting or sending wire. In order to increase the capacity in accordance with my invention, pieces of wire either in straight form or in form of coils are inserted or added—as, for example, as shown in Figs. 2 to 5.

In Fig. 2 the spark-gap is moved from the position *ac* to the position *ef*, thereby adding the lengths of wire *ab* and *dc* to the circuit.

Fig. 3 shows a modification of the arrangement shown in Fig. 2, in which the spark-gap is removed from the position *ac*, and the wires *ab* and *dc* are connected by a bridge *ef*, which may be moved in either direction for adjusting the oscillation-circuit, thereby altering the capacity, and consequently the energy. The circuit should be adjusted so that this capacity will be a maximum.

If the transmitter has been given its maximum of capacity by this means, the action may be further increased by adding to the free end A of the secondary coil *s* additional pieces of wire either in straight or coil form. (See Figs. 4 and 5.) These pieces may advantageously contain induction-coils and condensers, and are characterized by the fact that a certain number of windings give the maximum of capacity, which will be diminished both by increasing or diminishing the number of windings.

Figs. 6, 7, and 8 show the application of the invention to receivers for wireless telegraphy. In Fig. 7 a compensating coil is added to a primary circuit. This connection avoids the necessity of earthing. Fig. 8 shows additional pieces joined to the secondary circuit of the receiver.

Fig. 9 shows an arrangement whereby the asymmetry destroyed by the action of the sending-wire M may be restored by adding a compensating coil at the opposite side of the condensers, and Fig. 10 shows a further carrying out of this idea. The coil *p*, as shown in these figures, acts as an inductance-coil. In certain cases—as, for example, in the practice of wireless telegraphy in connection with moving objects, as ships or balloons—it is preferable to provide adjusting means to avoid asymmetric action, as by means of the bridge *ss*. (See Fig. 11.) Earth connection may be provided, as shown in this figure.

A preferred form of the additional pieces

is a form of resonator, the nature of which has been discovered by Hertz and his followers. A receiving apparatus employing a resonator is illustrated in Fig. 12. In the apparatus shown in this figure the electric wave passing down the receiving-wire is branched at A in two directions, AB and AD. If now the length of the two wires AB and AD is such that the difference is equal to one-half the length of the waves, the point BD will be in a phase difference of one hundred and eighty degrees. In the resonator a system of waves is produced rising up to a certain maximum. BD are peaks of the waves, so far as electric oscillations are concerned. An earth connection would therefore disturb the condition of resistance and be of no use. For the same reason no capacity is to be added to either of the ends B or D. The most simple arrangement is to make the length AB equal to zero, Fig. 13. Adding capacity, as by condenser C, in the sending-wire will not disturb the effect of the resonator, Fig. 14. The wave generated in the circuit AD is capable of producing induction in any circuit in its neighborhood.

Referring to Fig. 15, K represents a coherer or its equivalent; R, an inductive resistance; E, an element of a battery; G, a galvanometer or its equivalent, and C the condenser.

In using closed oscillation-circuits an arrangement may be employed, as shown in Fig. 16, where the end of the receiving-wire is connected to two condensers C' C'', which are joined by the circuit MPQ, the connection between the two condensers being marked U. One condenser may be used instead of two; but the use of two condensers is preferable, for the reason that the necessary adjustment is thereby made easier. The oscillations in closed circuits are much less sensitive to disturbances, and it is possible to add another shunt R (see Fig. 17) without altering the nature of the oscillations.

Figs. 16 and 17 are merely theoretical diagrams, the practical application of the principle shown thereby to a wireless-telegraph receiving system being illustrated in Figs. 18 and 19.

As shown in Fig. 18, the shunt may be used for receiving the coherer or its equivalent. The closed circuit may be used for inducing currents in the secondary circuit, which contains the coherer, as shown by Fig. 19. Conditions will determine whether it is preferable to use a closed or open resonator.

I claim—

1. In wireless telegraphy, the combination with a closed oscillation-circuit, of an added piece of wire for restoring the symmetry disturbed by the sending or receiving wire, substantially as described.

2. In wireless telegraphy, the combination with a closed oscillation-circuit, of an added piece of wire in the form of a coil for restoring the symmetry disturbed by the sending or receiving wire, substantially as described.

3. In wireless telegraphy, the combination with a closed oscillation-circuit, of an added piece of wire and a condenser for restoring the symmetry disturbed by the sending or receiving wire, substantially as described.

4. In wireless telegraphy, the combination with a closed oscillation-circuit, of an added piece of wire in the form of a coil and a condenser for restoring the symmetry disturbed by the sending or receiving wire, substantially as described.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

FERDINAND BRAUN.

Witnesses:
MARIA SCHORN,
SIEGFRIED BRAUN.

[fols. 1039-1042] DEFENDANT'S EXHIBIT AA

836

G. REUTHE.

ANTENNA ARRANGEMENT FOR WIRELESS SIGNALING OR THE LIKE.

APPLICATION FILED MAY 25, 1918.

1,314,095. Patented Aug. 26, 1919.



Fig: 1.

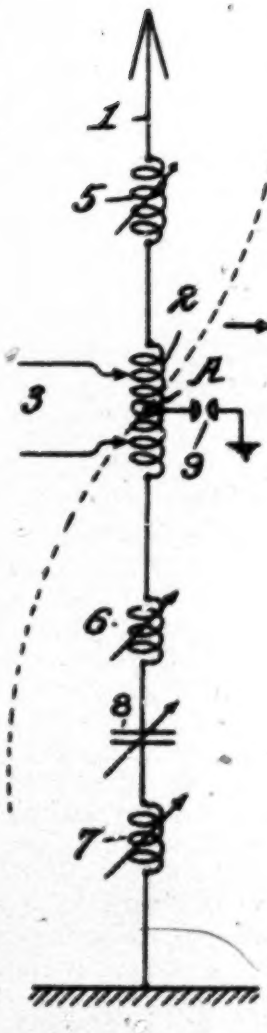


Fig: 2.

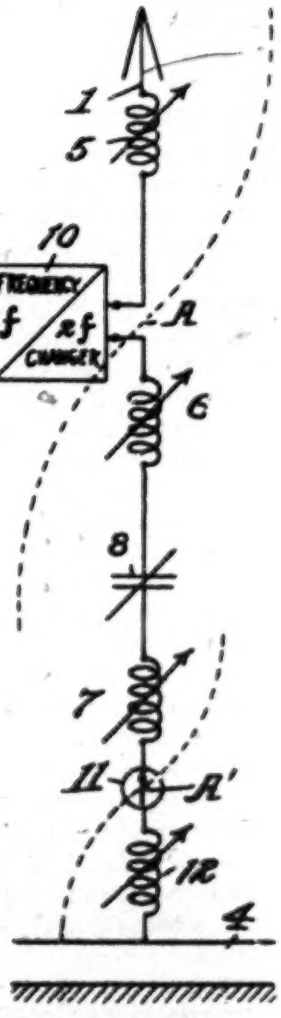


Fig: 3.

Gustav Reuthe
Inventor

By his Attorneys
Stanley & Burg

UNITED STATES PATENT OFFICE.

GUSTAV REUTER, OF SAYVILLE, NEW YORK.

ANTENNA ARRANGEMENT FOR WIRELESS SIGNALING OR THE LIKE.

1,314,095. Specification of Letters Patent. Patented Aug. 26, 1919.

Application filed May 25, 1918. Serial No. 236,752.

To all whom it may concern:

Be it known that I, GUSTAV REUTER, a subject of the German Emperor, residing at Sayville, Long Island, New York, have invented certain new and useful Improvements in Antennæ Arrangements for Wireless Signaling or the like, of which the following is a full and clear specification.

In antennæ for radiating electric oscillations, which are connected inductively or conductively with a primary circuit of any kind, the potential node may be located at any point of the antenna between its upper and lower end, depending upon the manner in which the capacity and inductance is distributed. I have found that it is of particular advantage to place the potential node of such antenna within that portion of it which is used for coupling. By this expedient above all the advantage is obtained, that between the antenna portion used for coupling and the primary circuit, or also between the primary circuit and ground, only comparatively low potentials exist. Therefore all insulations which may be necessary at such portions of the oscillation circuits may be made much lighter. Also protective devices which are frequently required at such points in this kind of antennæ can be entirely dispensed with.

The control of the location of the potential node may also be of great advantage in case measuring instruments, signaling keys, lightning, spark gaps, or any other apparatus used in the antennæ circuit or adjacent circuits for which a potential against ground is highly undesirable.

The expedient of suitably placing the potential node is important not only for the normal operation of a radio station but also when nearby atmospheric discharges set up additional oscillations in the antennæ which may be of very great amplitude.

The artificial control of the potential node in an antennæ is however of particular value in case so-called frequency changers are used such as are, for instance, described and illustrated in the patent to Arco-Meisner, Patent Number 1,151,566, patented May 25th. In an apparatus of this character, that portion of the antennæ which is used for coupling with the frequency changer is wound on an iron core. Moreover in such cases the distance between the iron core and the winding must be made as short as possible so as to avoid eddy currents in the iron core which may otherwise be produced by stray fields. Thus in such instance the danger of flash-overs from the winding to the iron core in case of unduly high potentials is particularly great. In such case also the primary winding of the apparatus and the rest of the station may easily be damaged.

The conditions which afford the placing of the potential node into a certain point A of an antennæ are that for both portions into which the antennæ is divided by this point A, the product of the effective capacity and the effective self-induction which controls the oscillations at the time must have the same value and must be equal to the product of the total effective capacity and self-induction of the entire radiation circuit. This condition can always be fulfilled by suitably distributing condensers and self-induction coils over the whole antennæ. Generally these elements are variable in steps or continuously. In case the wave length of the antennæ is changed it then becomes necessary to vary these elements simultaneously on both sides of the potential node.

In the accompanying drawings I have illustrated three modifications showing how my invention may be reduced to practice. Of course these modifications are only typical of the manner in which I propose to control the location of the potential node without limiting myself to the particular forms shown.

In these drawings Figure 1 shows the control of the potential node in an antennæ connected at its lower end to the counter-poise.

Fig. 2 shows the control of the potential node in an antennæ connected at its lower end to ground; and

Fig. 3 shows how two potential nodes may be produced in an antennæ if desired.

Referring now to Fig. 1, 1 is an antennæ, 2 a coupling coil for coupling the antennæ with any suitable primary oscillation circuit 3. 4 is the counter-poise and 5 and 6 are two variable inductance coils, one on each side of the coupling coil 2. It may be desirable to have the potential node of the antennæ located at the point A. The sum of the self-inductances 5 and 6 is given by the required wave length. Now by suitably varying the inductances 5 and 6 relatively

Page Tightly Bound

to each other, it is always possible to locate the potential node of the antenna at the point A.

Referring to Fig. 2, 1 is the antenna, 2 a coupling coil which in this case may be conductively coupled with a suitable primary circuit 3. In this modification the lower end of the antenna is directly connected to ground. It is again desired to place the potential node into the point A of coupling coil 2. For this purpose the inductance coils 5, 6 and 7 and the condenser 8 are provided, all of which elements are variable as shown. By suitably adjusting these elements as to relative values, the potential node can easily be placed into the point A. The most convenient way of determining whether the potential node is at the right point and for checking up the correct location, after the point has been determined, is to place a spark gap 9 of suitable size between point A and the ground as shown in Fig. 2. The elements 5, 6 and 7 are varied until the spark at gap 9 disappears. Of course any equivalent means for determining whether a potential exists between point A and the ground may be substituted for the spark gap.

Under certain circumstances it may be of advantage to have more than one potential node in the antenna. While one of these nodes may be located in the coupling coils, the other may be located in another apparatus contained in the radiation circuit. This modification is shown in Fig. 3. In this figure again 1 is the antenna, 4 the counter poise, and 10 the frequency changer of the character referred to above. 11 is an ammeter. It is now desired to have one of potential nodes located in the secondary of the changer 10 as at A and the other node located at the ammeter 11 as at A'. To accomplish this object, the inductance coils 5, 6, 7 and 12 and the condenser 8 are provided and distributed as to their location substantially as shown. Then the elements 5, 6, 7, 8 and 12 are suitably dimensioned so that the potential nodes are located at the points desired. It is of course obvious that for each given case the values of the condenser and inductances which determine the location of the node and of the wave length may be predetermined from the beginning without limiting the scope of my invention. Also it is obvious that in cases where only limited adjustments are required, only one or the other of these elements (condensers or inductances) may be made variable.

I claim:

1. The combination in a wireless signaling system of an antenna circuit, a frequency changer located therein and means for changing the natural frequency of said antenna circuit to locate the potential node of said circuit into said frequency changer comprising a plurality of inductances and a capacity distributed over said circuit and proportioned relatively to each other substantially as described.

2. The combination in a wireless signaling system of an antenna circuit, an output circuit of a frequency changer connected therein and a plurality of inductances and a capacity distributed over said circuit and adapted for adjustment to different oscillatory frequencies to locate potential nodes at predetermined points in said antenna circuit.

GUSTAV REUTHE.

[Second Edition.]

N° 14,449 A.D. 1899

Date of Application, 13th July, 1899
Complete Specification Left, 12th Apr., 1900—Accepted, 2nd June, 1900

PROVISIONAL SPECIFICATION.

Improvements in Wireless Telegraphy.

SIDNEY GEORGE BROWN, 22, Holland Road, Kensington, London, Electrical Engineer, do hereby declare the nature of this invention to be as follows:

This invention relates to improvements in wireless telegraphy especially in the method of arranging the radiating and receiving wires.

The transmitter and receiver may be provided with two vertical or horizontal wires, a wire coupled to each side of the spark gap, or receiving coherer, and placed approximately at say half a wave length apart, with or without an earth connection.

These wires may or may not be closed at the top, or joined through a small capacity, and a rectangular or other shape may be given to the wires so as to enclose an area.

If a spark gap at the generating station is provided with vertical wires, earth connections or other equivalent devices, the wave length the whole system shall generate can be settled and fixed by placing suitably shaped insulated conductors between the two outer spark balls, or by arranging the immidiate surroundings of the spark gap, by these means a reflector preferably constructed of straight or wire gauze can be placed behind such radiating wires, and within a much shorter distance than the whole or half length of such vertical wire.

Instead of an earth connection, the other side of the spark gap may be coupled to the reflector which may be insulated, the vertical wire being held in place by suitably shaped insulators fixed to the reflector.

I have found it convenient in many cases especially if the vertical wire was connected to one of the middle balls of the spark gap to place a small capacity across the high-pressure terminals of the spark coil, an inductive circuit being placed if necessary between such capacity and the spark balls.

It might in many cases be more convenient to multiply the number of radiating systems rather than increase the height of the wires.

In this case it would seem convenient to have separate windings on one spark coil for all the systems, while if the receiver was to be treated in a similar way I should place vertical wires one behind the other and having some relation to the wave length, and coupled in series.

Dated this 13th day of July 1899.

SIDNEY GEORGE BROWN.

[Price 8d.]

AM/8

840
1044

COMPLETE SPECIFICATION.

Improvements in Wireless Telegraphy.

SIDNEY GEORGE BROWN, 9, Putney Hill, Putney, "late of" 22, Holland Road, Kensington, London, Electrical Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:

According to this invention the transmitting apparatus is provided with two radiating wires coupled one to each terminal of the sparking device and the receiving apparatus is provided with two receiving wires coupled one to each terminal of the coherer.

These radiating and receiving wires are respectively placed at a distance apart which has a definite relation to the length of the signalling waves, that of half or a wave length being a convenient distance.

The said wires may be closed at the top or not and they may or may not be provided with an earth connection.

This placing the wires half a wave length apart causes the system to send its waves or receive them from mainly one direction, which direction would seem to be that of the plane of the wires.

If the vertical wires were not so carefully adjusted to the wave length they would transmit or receive the Hertzian waves from any direction.

The vertical wires may or may not be closed at the top or joined through a small capacity and a rectangular or other shape may be given to the wires, and the rectangle may consist of more than one turn of wire, so as to enclose an area.

By arranging a condenser across the high potential terminals of the spark coil and joining the terminals of this condenser to the spark balls through highly inductive coils I can increase the persistance of the waves: the condenser acting as a storage of power, and maintaining the potential at each side of the spark gap.

The highly inductive coils prevent the charge in the condenser from itself oscillating across the spark gap.

By thus increasing the persistance of the train of Hertzian waves due to each disruptive discharge, the receiving circuit can be caused to be in tune or synchrony with the transmitting circuit, thus rendering the system more sensitive and less likely to be interfered with by neighbouring systems differentially disposed.

The wave length that any system may generate is to a certain extent under command and it is necessary if parabolic reflectors are to be used to keep the waves short.

This can be done by suitably arranging the spark gap, such as by employing suitably sized intermediate balls or by placing inductive coils on the arms of the radiating wires.

By thus keeping the length of the waves short the use of parabolic mirrors behind the radiating and receiving wires and within a much shorter distance of said wires than that of their length or half their length as has heretofore been thought necessary is rendered possible.

These mirrors which should be constructed of reticulated metal such as fine wire netting or its equivalent, have the effect of reflecting the waves to, or receiving them from one definite direction and thereby restricting the wave or telegraphic effect to a given direction.

In order that my invention may be clearly understood and readily carried into effect I will proceed to describe the same more fully in connection with the accompanying drawing in which.

Figures 1 and 2 are respectively diagrams of transmitting apparatus and

A6/1

receiving apparatus in which the radiating and receiving wires project vertically into the air.

Figures 3 and 4 are respectively diagrams of transmitting apparatus and receiving apparatus in which the radiating and receiving wires are put to earth.

Figure 5 shows a parabolic mirror in position behind a radiating or a receiving wire arranged according to this invention.

Referring to Figures 1 and 2, a and a^1 are the radiating wires of the transmitting apparatus, a^2, a^3 are the receiving wires of the receiving apparatus and are preferably arranged in the same plane with the wires a a^1. b is the battery and t is the transmitting instrument, in the primary circuit of the induction coil C of the transmitting apparatus.

K is a condenser placed across the high potential terminals of the secondary winding of the induction coil C.

S S S are the spheres or balls of the sparking device.

L L^1 are inductive coils placed between the terminals of the condenser K and the terminals of the spark balls S S, the ends of the radiating wires a a^1 at one extremity being also respectively connected to the terminals of the said spark balls.

V is a rotary vibrator of well known construction placed in the primary circuit of the coil C.

R is the receiving relay or other receiving instrument b^1 is the battery in the circuit of the receiving relay d is the coherer in the receiving relay circuit, to the terminals of which coherer the wires a^2 a^3 are connected.

L^2 L^3 are inductive resistances placed respectively between the terminals of the coherer d and the receiver R and battery b^1 but in many cases L^2 L^3 are unnecessary as the relay winding R does usually, and the shunting resistance, if used, may possess sufficient induction of their own.

Upon depressing the key of the transmitter t: which for high speed working would be replaced by a Wheatstone transmitter: the circuit of the battery b is closed and the primary winding of the coil C is energized through the vibrator V in the well known manner.

For fast speed signalling this vibrator V which makes and breaks the current for the primary winding of coil C, should be kept constantly working whether the coil C is energized or not.

When the coil C is thus energized sparks pass between the balls S and the Hertzian waves thereby generated, are radiated by the wires a a^1. The condenser acts as a storage of power, maintaining the potential at each side of the spark gap and thereby increasing the persistance of the waves.

The coils L L^1 prevent the charge in the condenser from itself oscillating across the spark gap, whilst permitting the currents from the secondary winding of the coil C to pass steadily to the spark balls.

When no signals are received the coherer d is maintained in a decohered or non-conductive condition, and the circuit of the receiver R and battery b^1 is consequently open.

When the signalling Hertzian waves are received by the wires a^2 a^3 the said waves pass through the coherer d rendering it conductive and closing the circuit of the receiver R and battery b^1 the signals being recorded by the said receiver.

The radiating wires a a^1 and also the receiving wires a^2 a^3 are respectively placed at a distance apart which has a definite relation to the length of the Hertzian waves generated.

This distance may be conveniently half that of the Hertzian wave length, such an arrangement causing the positive radiating wire to supply the positive crest of the wave at the same time as the negative radiating wire supplies the negative crest of the wave and the waves to be thus transmitted or received mainly in the direction of the plane of the radiating and receiving wires.

In Figure 3 the battery b, transmitter t vibrator V, induction coil C, condenser K and sparking spheres S are arranged as in Figure 1.

The radiating wires a a^1 are respectively connected to earth plates E E and are preferably arranged at a distance of half, one and a half, or more wave length apart.

K^1 & K^2 are condensers respectively inserted between the terminals of the spark balls and the radiating wires a a^1.

In Figure 4 the recording instrument R the battery b^2 the inductive resistances L^2 L^1 and coherer d are arranged as in Figure 2.

The receiving wires a^2 a^3 are connected respectively to earth plates E E and are preferably arranged at a distance of half, one and a half, or more wave length apart and in the same plane with the wires a a^1.

K^3 and K^4 are condensers respectively inserted between the terminals of the coherer d and the receiving wires a^2 a^3.

The operation of the apparatus shown in Figure 3 and 4 is substantially the same as that shown in Figure 1 and 2.

The condensers K^1 K^2 prevent the radiating wires a a^1 being short circuited by earth and the condensers K^3 K^4 prevent the receiving wires a^2 a^3 being short circuited by earth.

The radiation (with the apparatus shown in Figures 3 and 4) keeps to the surface of the ground.

By arranging the inductive coils L L^1 and the condenser K as above described the Hertzian waves are kept persistant.

The persistance of the waves enable the transmitting and the receiving wires to adjusted in tune or syntony, so that they will be more sensitive to one another and will not be likely to be interfered with by differentially disposed neighbouring systems.

The shortness of the waves enable a parabolic mirror of wire gauze or its equivalent as c in Figure 5 to be placed a short distance behind the vertical wire a, or wires, for the purpose of reflecting the waves in a definite direction.

One side of the spark gap, instead of being earthed may be connected to the mirror c which latter would then be insulated; or if one side of the spark gap is earthed, the mirror may be also earthed, but not insulated.

In all the foregoing I may multiply the systems, coupling the wires in parallel or in series as the case might be.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:—

1. In wireless telegraphy, the combination with the transmitting or receiving apparatus of two radiating or receiving wires, attached one to each side of the spark gap or coherer substantially as described.

2. In wireless telegraphy, the combination with the transmitting or receiving apparatus of two parallel vertical radiating or receiving wires attached one to each side of the spark gap or coherer and arranged at a distance apart which has a definite relation to the length of the signalling waves, substantially as described for the purpose specified.

3. In wireless telegraphy the combination with the transmitting or receiving apparatus of two wires attached one to each side of the spark gap or coherer, the ends of the wires being earthed substantially as described.

4. In wireless telegraphy the combination with the transmitting or receiving apparatus of two wires attached one to each side of the spark gap or coherer, the ends of the wires being connected to earth plates, which are placed at a distance apart which has a definite relation to the length of the signalling waves, condensers being inserted in the path of the wires substantially as described and for the purpose specified.

5. In wireless telegraphy the combination with the transmitting or receiving apparatus of two wires attached one to each side of the spark gap or coherer and bent so as to enclose an area.

N° 14,149.—A.D. 1900.

Brown's Improvements in Wireless Telegraphy.

6. In wireless telegraph apparatus the combination with the transmitter, the battery, the induction coil, the sparking spheres, and the radiating wires of a condenser placed across the high potential terminals of the induction coil, and inductive coils placed between the terminals of said condenser, and the terminals of the sparking spheres, substantially as described and for the purpose specified.

In wireless telegraphy, a parabolic metallic parabolic mirror or reflector placed behind the wave radiating or receiving wires substantially as described.

Apparatus arranged substantially as described and illustrated in the accompanying drawings.

Dated this 11th day of April 1900.

SIDNEY GEORGE BROWN.

Edinburgh: Printed for Her Majesty's Stationery Office, by Neill & Co., Ltd.
(5,326) 125.-6/01.

48
A.D. 1899. JULY 13. N° 14,449.
BROWN'S COMPLETE SPECIFICATION. 1 SHEET.

Fig. 1.

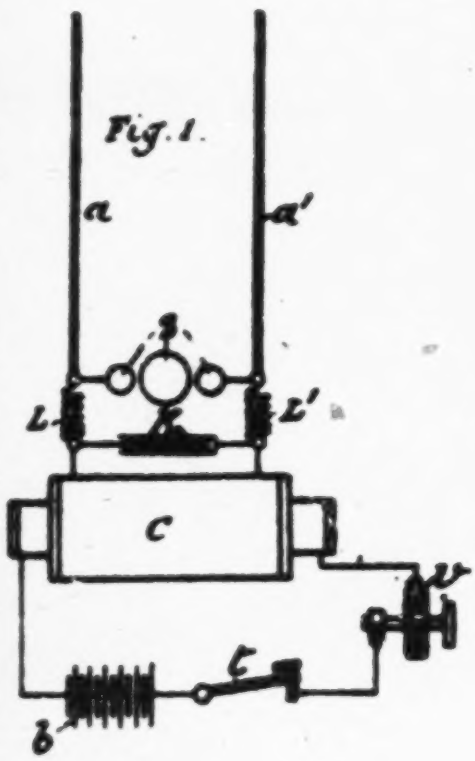


Fig. 2.



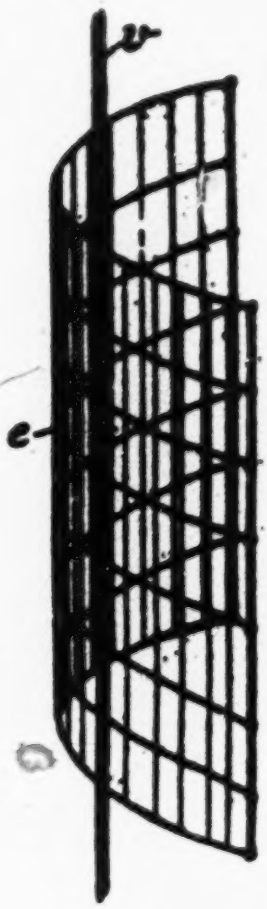


Fig. 5.

Fig. 3.

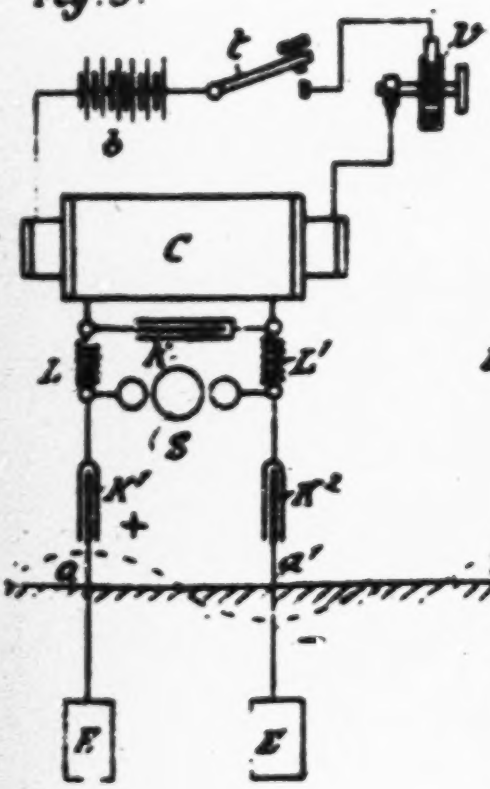
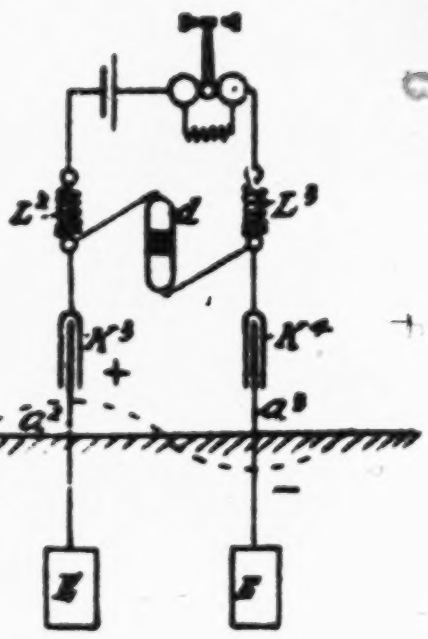


Fig. 4.



[This Drawing is a reproduction of the Original on a reduced scale.]

[fols. 1049-1064] DEFENDANT'S EXHIBIT AA

846

Nov. 24, 1925. 1,562,961

R. A. HEISING

DIRECTIVE RADIO TRANSMISSION SYSTEM

Filed May 16, 1921 4 Sheets-Sheet 1

Fig. 1

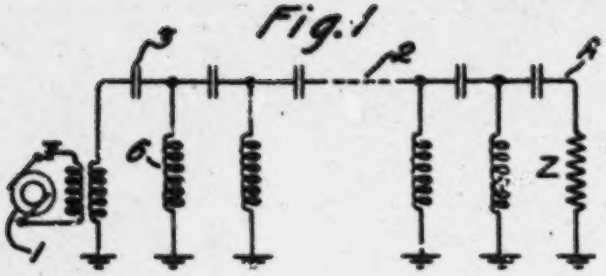


Fig. 2

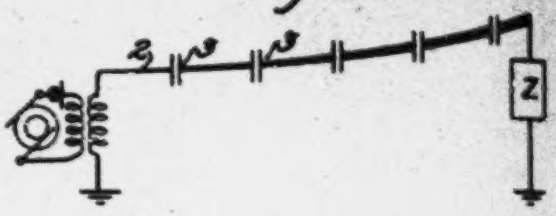


Fig. 4

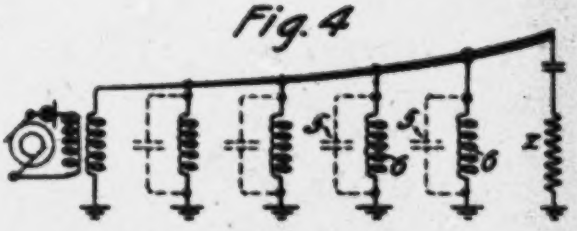


Fig. 5

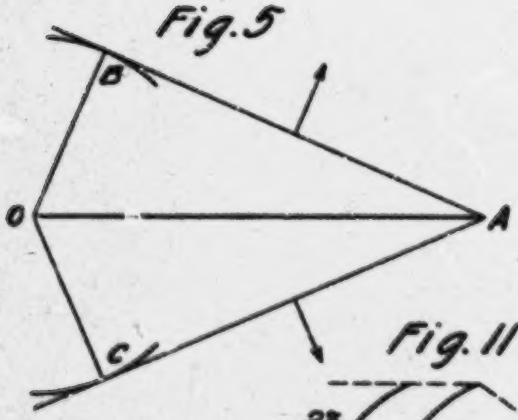


Fig. 3



Fig. 11

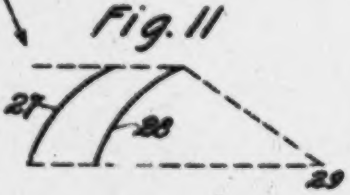


Fig. 6

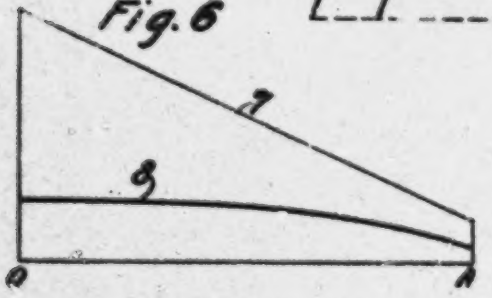


Fig. 10

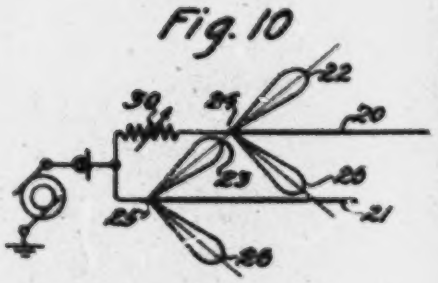


Fig. 7

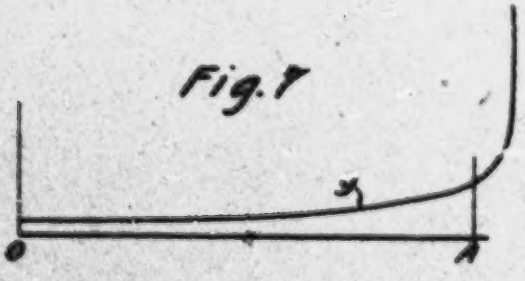
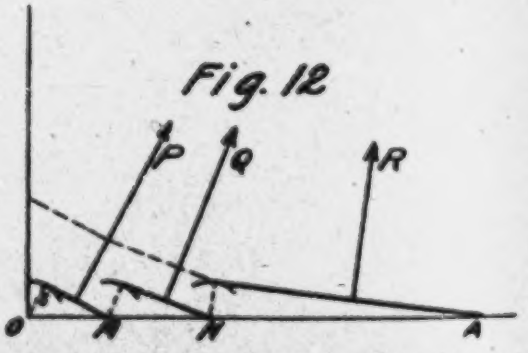


Fig. 12



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R. A. HEISING

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Fig. 8.

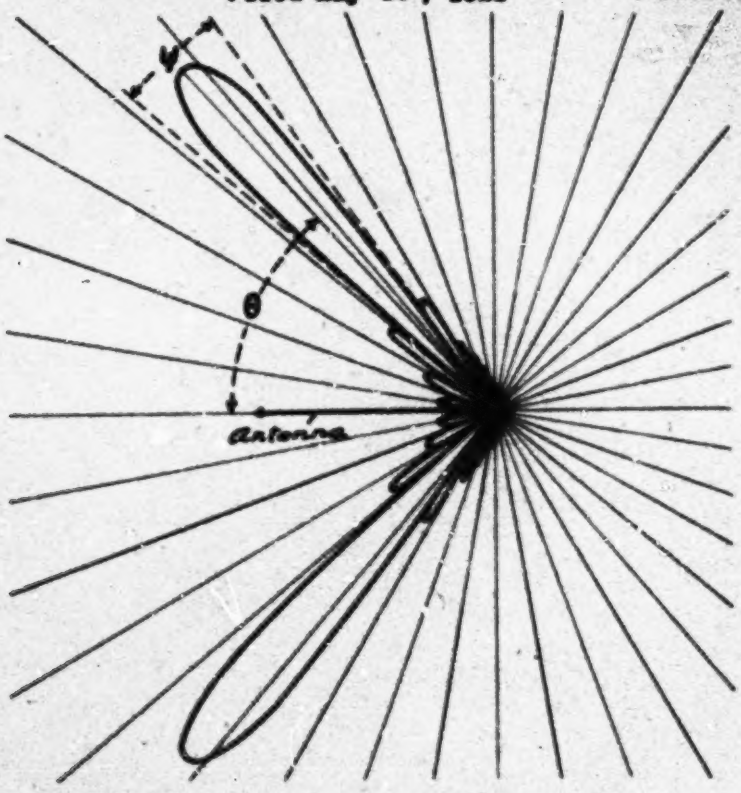
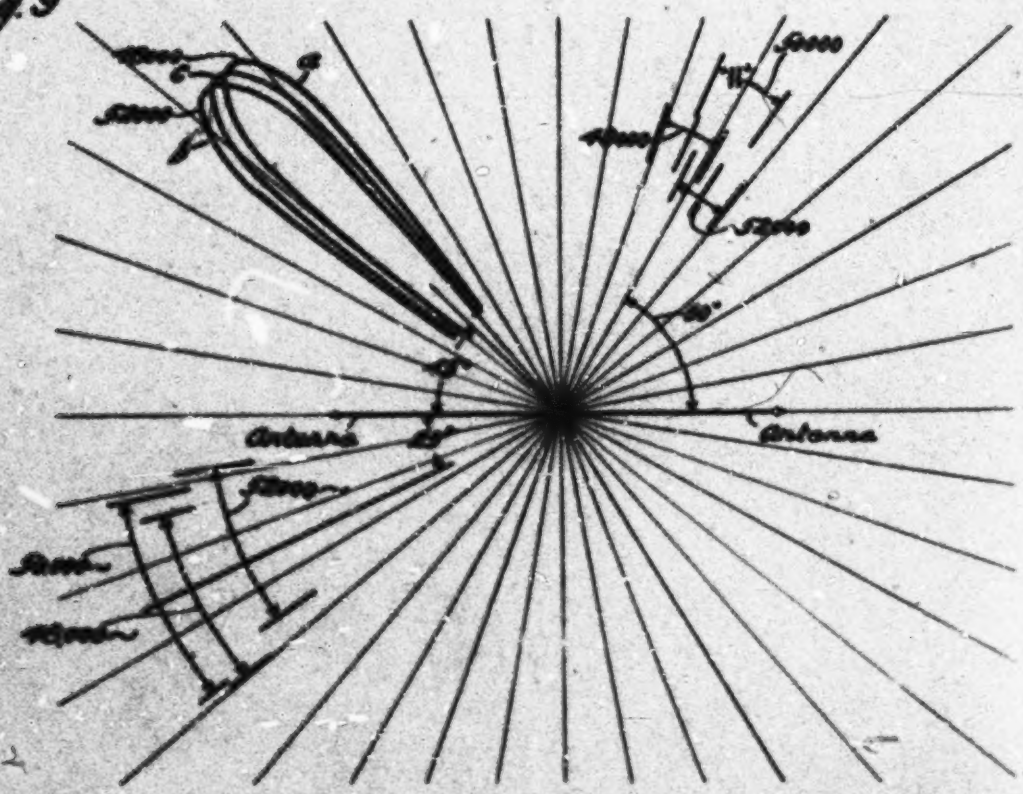


Fig. 9



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Fig. 13

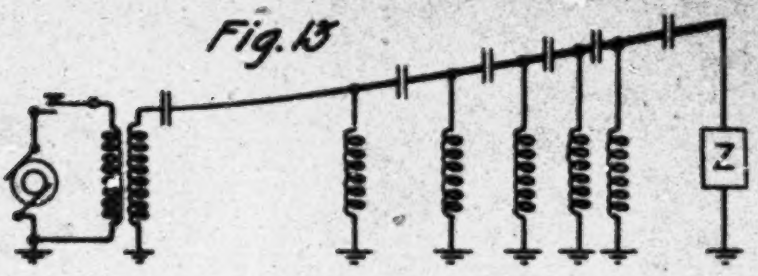


Fig. 14

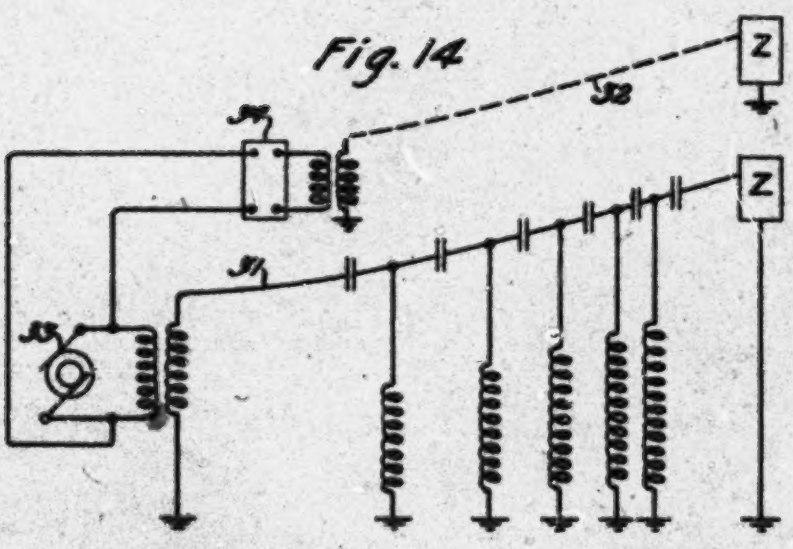


Fig. 16

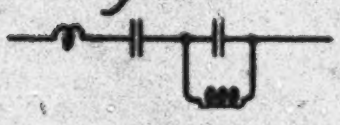


Fig. 15

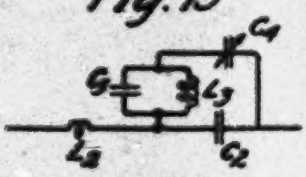


Fig. 17



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Fig. 18

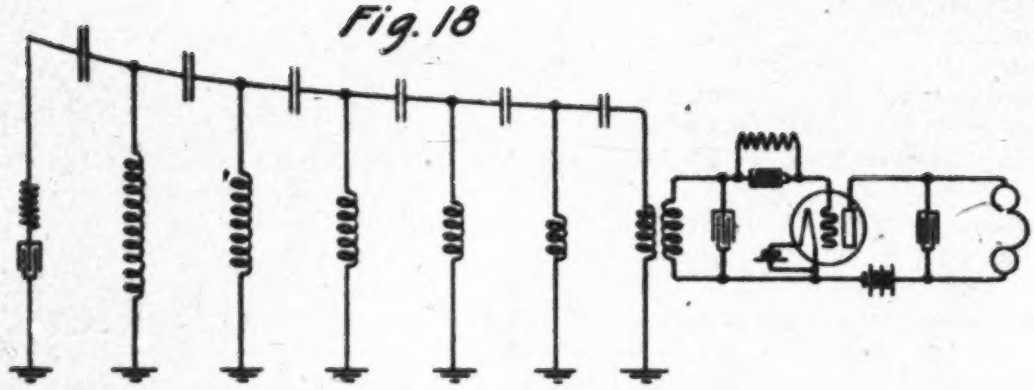
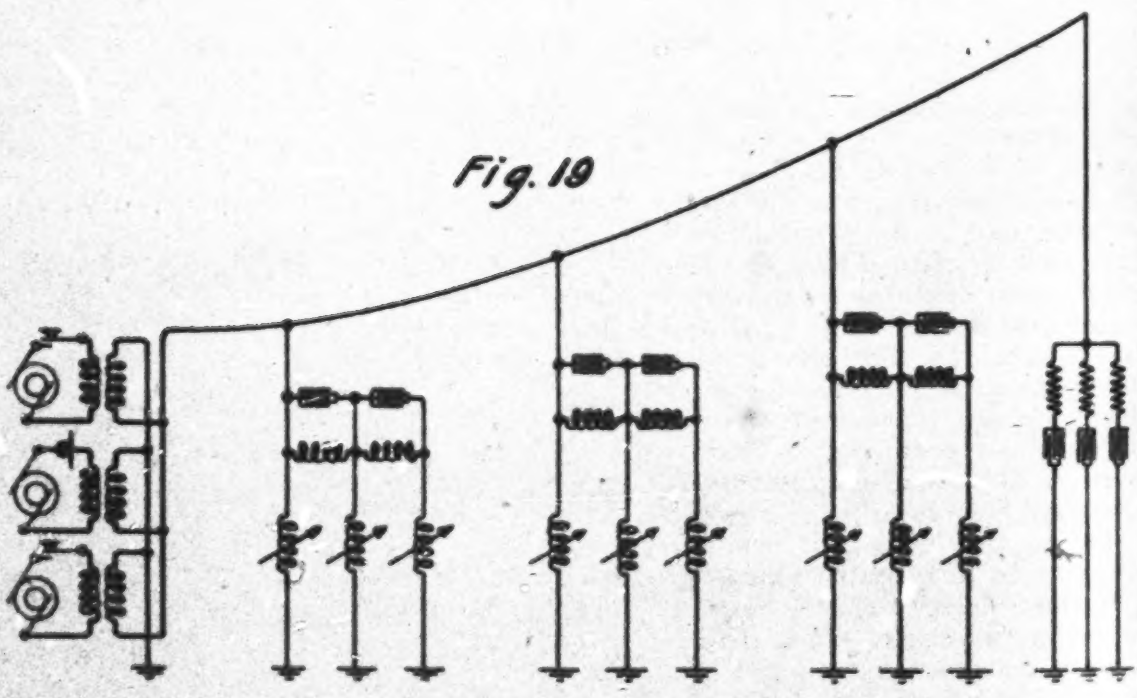


Fig. 19



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1,562,961

Patented Nov. 24, 1925.

UNITED STATES PATENT OFFICE.

RAYMOND A. HEISING, OF MILBURN, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

DIRECTIVE RADIO TRANSMISSION SYSTEM.

Application filed May 16, 1921. Serial No. 470,043.

To all whom it may concern:

Be it known that I, RAYMOND A. HEISING, a citizen of United States of America, residing at Milburn, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Directive Radio Transmission Systems, of which the following is a full, clear, concise, and exact description.

This invention relates to directive transmission of energy and more particularly to methods of and systems for directively radiating and absorbing electric waves.

An object of the present invention is to provide a transmission system for radiating energy directively. Another object of the invention is to provide a focussing antenna which will concentrate the radiated energy at a distant point.

The propagation velocity of wave in any medium is in general the product of its frequency and its wave length in that medium. In the case of free electric waves, the propagation velocity is approximately 300,000,000 meters per second. In the case of guided electric waves, the wave length and the wave propagation velocity are functions of the electrical constants of the guiding transmission conductors. As given by Heaviside, the wave lengths of a sustained wave over a circuit having uniformly distributed inductance and capacit. is

$$(1)\quad \lambda = \frac{2\pi}{\sqrt{\frac{1}{2}\left\{\sqrt{(SR+\omega^2LC)^2+\omega^2(LS-CR)^2}-(SR-\omega^2LC)\right\}}}$$

where λ is the wave length, ω is the angular velocity or the wave frequency multiplied by 2π and S, R, L, and C are respectively the shunt conductance, series resistance, series inductance, and shunt capacity of the circuit per unit length. This wave length evidently depends upon the magnitudes of these four electrical characteristics per unit length of the circuit. By varying these it is possible to increase or decrease the wave length of the sustained wave and accordingly to vary the wave propagation velocity along the circuit. If a loaded circuit of this character is used for radiating or absorbing electric waves, the waves, if sustained sine waves, may be propagated along the circuit at a greater velocity than that at which they progress in the ether. If a definite small part of a transmitting antenna be considered, the energy of the wave proceeding from that part will be partly propagated along the circuit as a guided wave and partly radiated and propagated out through the surrounding space. The shape of the resultant wave front in the ether will be dependent upon the relative velocities of wave propagation in the two media. It is, therefore, possible to give a radiated wave variously directed fronts depending upon the loading of the antenna circuit. It is likewise possible to so absorb the directed radiant wave at a receiving antenna as to cause all of the absorbed energy to cumulatively affect the receiving device.

According to the present invention a radio transmitting or receiving antenna is made long with respect to the wave-length of the wave to be transmitted or received. In order to make this antenna behave as a conductor of infinite length and thereby avoid the production of a reflected wave, it is desirable to terminate it in an impedance element having an impedance equivalent in magnitude and character to the iterative or surge impedance of the antenna itself at the terminating point. At intervals corresponding to a fraction of a wave-length, the antenna is loaded by inserting series capacity or shunt inductance or both to make its wave propagation velocity for the waves to be transferred higher than the corresponding wave propagation velocity in ether. Since the energy in a radiating antenna decreases with increasing distance from the source, it is desirable in order to secure the best results to progressively increase the radiating factor of the antenna and this is done by increasing its height.

The invention permits radiation in one lateral direction to the substantial exclusion of radiation in any other by an arrangement of parallel antennæ. For focussing on a

fixed receiving point the loading of the transmitting antenna may be progressively increased so as to progressively change the direction of the wave front of the emitted wave. The antenna may also be curved laterally to add to the focussing effect. For multiplex operation, waves of a plurality of different frequencies may be focussed at the same or different points by loading the antenna in different manners for waves of each of the different frequencies.

Other objects of the invention will be apparent upon consideration of the following detailed description taken in connection with the accompanying drawing in which Figure 1 illustrates diagrammatically a loaded antenna long with respect to the wave length of the emitted wave; Figure 2, a radio transmission arrangement including series capacity loading for increasing the wave propagation velocity; Figure 3, a unit section of the conductor of Figure 2; Figure 4, an antenna system provided with shunt inductance loading; Figure 5, a diagram indicating the directive operation of loaded antennæ; Figure 6, a diagram of current and energy distribution in antennæ of the type disclosed; Figure 7, the radiating coefficient diagram for antennæ of this type; Figure 8, a polar diagram showing the distribution of the radiated wave amplitude in various angular zones; Figure 9, a polar diagram showing the distribution of energy of a modulated carrier wave; Figure 10, an antenna system for neutralizing the directed energy in one direction; Figure 11, an arrangement of laterally curved antennæ for focussing energy at a distant receiving station; Figure 12, a diagram indicating the operation of a second type of focussing system depending upon progressive change in loading; Figure 13, an antenna arrangement for this second type of system; Figure 14, a directive focussing system employing both capacity and inductance loading; Figures 15 to 17 illustrate details of loading arrangements applicable to any of the foregoing systems; Figure 18, a receiving system with a loaded antenna; and Figure 19, a multiplex system for focussing a plurality of different waves.

Referring to Figure 1, a source 1 is associated with an antenna 2 to supply energy thereto for radiation. Antenna 2 is preferably of a length several times the wave-length defined in equation (2). This wave-length depends upon the inductance and capacity per unit length of the radiating circuit. In loaded telephone lines with inductance, as in the common practice, the wave-length is greatly shortened. In fact, in loaded line telephone practice, the wave-length multiplied by the frequency may give a velocity of the order 60,000,000 meters per second instead of 300,000,000 meters per second which is the velocity of light and of free electric waves. Since increasing the inductance per unit length which is done in loading telephone lines, shortens the wave-length at a given frequency, it will be evident that it is possible by reducing the inductance per unit length, to increase the wave-length of a unit circuit. If the resistance and shunt conductance of the circuit are made zero, equation (1) reduces to

$$(2) \quad \lambda = \frac{2\pi}{\omega\sqrt{LC}}$$

From equation (2) it would appear that, with circuits of negligible series resistance and shunt conductance per unit length, either reducing the series inductance per unit length or the shunt capacity per unit length, should increase the wave length and, therefore, increase the velocity at which a given frequency wave is propagated along the circuit. This can actually be accomplished in several ways it being remembered that the long antenna with its capacity to ground and the return ground conducting path may, if uniform and if properly terminated, be treated as any other alternating current conducting circuit. One simple way to increase the velocity of the wave propagation is illustrated in Fig. 1 in which series loading capacities 3 and shunt inductances 6 are inserted in the conducting line and are spaced much in the same manner as are the loading inductances in loaded telephone lines. These loading inductances and capacities should be separated by distances small compared to a wave length, so that the effect of uniform distribution of the capacity is approximated. Although the exact number of such elements may vary greatly, it is desirable to use eight or more per unit length. For simplicity only a few elements are shown. The action of this capacity loading is to introduce series reactance opposite in sign to that of the natural series inductance, and accordingly to produce lower effective series inductance per unit length. The action of the inductance loading is to introduce shunt reactance opposite in sign to that of the natural shunt capacity and hence to produce lower effective shunt capacity reactance per unit length. It will, of course, be understood that either series capacity loading or shunt inductance loading alone may be used.

As has been previously mentioned, a circuit of this character of finite length must be properly terminated to avoid having a wave reflected from the free terminal. A reflected wave produces nodes along the circuit and introduces complications of various sorts. If the transmitted wave gives directive radiation in the general direction of its transmission the reflected wave will give

directive radiation in the opposite direction. To eliminate the reflected wave and prevent this reverse transmission, it is only necessary to terminate the line with a proper impedance Z, the value of which may be computed from well known transmission equations.

Fig. 2 illustrates a modification of the arrangement of Fig. 1 in which series capacity loading is employed. Conductor 2 is progressively elevated to increase the radiating factor so as to maintain the energy radiation as nearly equal as possible at all points along the antenna. To maintain the unit shunt capacity constant with increasing height a conductor of increasing size is employed. An element of the recurrent network thus formed is illustrated in Figure 3, in which the natural series inductance 4 and shunt capacity 5 of the conductor, both indicated by dotted lines, constitute together with the loading capacity 3 a uniform section of the line.

Fig. 4 illustrates another method of antenna loading which consists in reducing the effective shunt capacity of the circuit. This is accomplished by connecting between the line and ground, loading inductances 6 which are preferably spaced eight or more to the wave length, although in this case as well as in the case of the series capacity loading, a considerable variations in this number may be permitted. It is a well known fact that the effective capacity of a condenser is reduced by connecting in parallel with it a large inductance. The effective reactance of the condenser is increased. At a given frequency the natural capacity 5 of a unit section of the conductor with the inductance 6 shunted around it has several times the capacitative reactance which the capacity 5 alone has. Resistance tends to shorten the wave length. It is accordingly desirable to make the resistance of the antenna conductor very low. In loading systems of the kind described, the variations in effective capacity or effective inductance will be particularly marked for a given frequency, and wave velocities for such frequencies may be attained exceeding that of light.

The fact that a wave may be made to travel over a circuit with a velocity greater than that of free electric waves or light, may be made use of in directive transmission. Referring to Figure 5 in which OA represents a plan or top view of a long loaded antenna of the type illustrated in Figures 2 and 3, suppose that the source of waves is located at terminal O. An electrical disturbance occurring as an alternation of electrical potential at this point travels along the circuit to a point A. By radiation point O becomes the center of a disturbance of like form which emanates in all directions through space. If the space velocity, i. e., the velocity of free electric waves is such that the radiated wave travels a distance OB during the time that the guided wave travels the distance OA, the wave front of the radiated wave in the space surrounding the antenna will take the directions BA and CA. The direction of propagation of the radiated wave being perpendicular to this front is indicated by the arrows. The angle between this wave front and the antenna evidently depends upon the ratio of the guided wave velocity to the free wave velocity. If right angle triangles are drawn similarly to Fig. 5 for the case where the base OA equals the radii OB and OC, the hypothenuses AB and AC will be infinitely short and at right angles to the base OA. This illustrates the critical case in which the ratio of velocities is unity. When this ratio is unity, the wave will accordingly be propagated in the direction of transmission along the circuit, i. e., OA. The physical basis for the phenomenon when the ratio is unity is made readily apparent by noting that as the wave is radiated in the direction of antenna OA, since the wave is propagated along the antenna at the same velocity, new centers of oscillation are continuously being established on the wave front which in turn gives rise to waves which travel in the direction OA coincidentally with those from the original wave source O and having the same phase. There accordingly results a reenforcing of the wave in the direction OA. The original wave and the waves radiated from these centers of oscillation in the opposite direction are opposed in phase and mutually extinguish each other. When the ratio is infinite the wave front will obviously be parallel to the conductor and the direction of propagation will be perpendicular to the antenna. When this ratio is less than unity, the antenna is not directive.

In Figure 4, the terminating element Z is shown as comprising series resistance and capacity. That the terminating impedance may be closely approximated by resistance alone will be evident from a consideration of the specification of United States patent to Heising 1,313,483, patented August 19, 1919.

In order to secure best results, the directed wave should be of uniform intensity throughout its wave front. This requires that the radiation in power should be the same for each unit length along the line. In a line having uniform resistance, inductance, and capacity, the current decreases logarithmically, and the radiation will accordingly be non-uniform. If the energy is to be uniformly radiated, the remaining energy in the guided carrier wave should decrease uniformly from the terminal O of the antenna to the terminal A, where the remainder of the energy should be absorbed by the terminating impedance Z. In order

to secure an energy distribution of this character as illustrated by line 7 of Figure 6, the current along the circuit must vary as the square root of the energy as represented by curve 8 of Figure 6. In order that the radiated power may be uniform along the line with decreasing current, it will be evident that the radiating constant of the antenna or its radiation resistance must be gradually increased along the line. It should vary according to the reciprocal of the square of the current amplitude, as indicated by curve 9 of Figure 7 which represents the radiation coefficient or radiation resistance. Since the radiation resistance varies approximately as the square of the height of the line, this variation in resistance may be secured by varying the height of the line so as to make this height approximately proportional to the square root of the required radiation resistance. This is indicated in Figures 2 and 4 in which the height of the line increases from the source to the remote terminal in accordance with the requirement just stated. The gradually increasing height with decreasing current will produce uniform radiation throughout the length of the conductor. Inasmuch as the energy remaining at A is absorbed in the terminating network Z, it is possible to terminate the line at such a point that the height of the antenna will not, because of the very small current, be required to exceed practical limits in order to maintain constant radiation.

With an antenna of varying height and a constant size conductor, the inductance and capacity per unit length will change. It is possible to progressively vary the magnitudes of the loading reactances along the line so as to maintain the wave velocity constant. As an alternative method the diameter of the conductor itself may vary progressively with the height. With this latter arrangement the loading inductances and capacities may remain the same per unit wave length if a constant wave velocity is to be maintained throughout the length of the conductor. Figures 2 and 4 indicate a variation in the diameter of the conductor to maintain the capacity per unit length substantially constant.

Figure 8 shows a complete radiation curve with the wave amplitude as a function of its angular direction from a particular loaded line antenna of twelve times the wave length. The position and direction of extension of the antenna is indicated by the arrow. The principal energy falls within a sector of a 14° angle marked ϕ. Small amounts fall in other directions due to interference. Increasing the length of the antenna to twenty-four wave lengths would cut the angular width of the transmission loop in two and would reduce the size of the small loops representing power transmitted in other directions.

In radio telephony when modulating a carrier wave in accordance with speech, a band of waves of different frequencies results. If for example, a carrier wave of 50,000 cycles frequency is used and the range of the frequency of essential speech currents is about 2,000 cycles, the modulated energy will have frequencies ranging from 48,000 to 52,000 cycles. In a system of this kind these various frequency waves will travel along the loaded antenna with different velocities due to the fact that the effective inductive reactance or effective capacitive reactance per unit length changes with frequency. If a carrier wave of 50,000 cycles frequency is radiated from an antenna twelve wave lengths long, at a 45° angle, as shown by the curve of Figure 9, the 48,000 and 52,000 cycle frequency waves will be spread out in different directions, as shown by curves *a* and *b* respectively of the same figure. In this case the dispersion is not particularly harmful as there is sufficient amplitude of both of the extreme frequency waves occurring in the 45° angle direction to give a very good signal. Similary, if waves of this frequency are radiated in a 25° direction, as shown in the same figure, there will be a good quality of speech transmitted from the energy produced over an angle several degrees in width. If, however, the transmission angle is 60°, as shown in the same figure, the 52,000 and 48,000 cycle waves overlap very slightly and a change in quality is apt to result. In Fig. 9, the position and direction of extension of the antenna is indicated, for the respective directions of maximum directivity, in a manner similar to that of Fig. 8.

The transmission angle depends upon the propagation velocity. A larger transmission angle accordingly requires a larger propagation velocity which in turn causes a larger difference between the propagation velocities along the line, of the different frequency components. Accordingly the differences in direction of the various frequency components, are accentuated as the transmission angle of the band as a whole is increased. If waves of frequencies lower than 50,000 cycles are used as a carrier, these variations will become still larger and it is, therefore, of advantage to use high carrier frequencies.

As is diagrammatically indicated in Fig. 5, there is directive radiation in two lateral directions. An arrangement of multiple antennæ for suppressing radiation in one of these directions is illustrated in Figure 10 in which parallel directive antennæ 20 and 21 are so spaced that their respective energy transmission loops 22 and 23 from the terminals 24 and 25 connected with th

source extend in the same direction, and neutralize in space. If energy of the same phase is simultaneously supplied at points 24 and 25, and if these points are a half wave length apart in one direction in which their respective antennæ radiate most powerfully, the effect of the energy radiated from point 25 will be to oppose and neutralize that radiated from point 24 in this direction. This is for the reason that for all points in space in this direction these radiated energies will be opposite in phase. In other words loop 22 will neutralize loop 23. If the distance between the points 24 and 25 does not correspond to a half wave length, the phase of the energy supplied to one of the antennæ may be so shifted by a variable impedance device 30 that the points 24 and 25 will tend to radiate energies which will neutralize in space in the direction of the loops 22 and 23. This will leave only the loops 26 which are similarly directed and which are additive.

If it is desired to focus on a distant station, the directive antenna may be curved in direction as indicated in Figure 11 in which the two curved antennæ 27 and 28 are each given such curvature as to focus the radiated energy on a receiving station at 29. In general, in the case of curved antennæ it will be possible to obtain only roughly approximate neutralization by the use of two antennæ. Certain special cases, as for example, that where the antennæ extend along arcs of concentric circles and are arranged to focus their radiated energy at the center may give fairly exact neutralization.

A focussing effect could also be obtained by increasing the wave propagation velocity along the line so that in the region of one terminal of the line, the wave will be propagated at a greater rate than in the region of the other terminal. The operation of this will be clear from an inspection of Figure 12, in which an antenna OA is so loaded that a wave of given frequency applied at O will be propagated, in the first unit of time from O to M, in the second unit from M to N, in the third unit from N to A. Suppose that each portion OM, MN, and NA is, throughout its length, composed of like recurring sections. If the propagation velocity of the unguided waves when radiated be OS per unit of time, the radiated wave from portion OM will have a front, the direction of propagation of which is indicated by arrow P. The direction of the radiated wave of portion MN will be as indicated by Q, and that from portion NA as indicated by R. If the loading is made to progressively vary so that the wave length progressively varies, a smoothly curved wave front will obviously result. Figure 13 indicates diagrammatically an antenna loaded in this manner by a progressively closer spacing of the loading capacity or shunt inductance elements, or both. Instead of closer spacing of capacity elements of the same size the capacitances of the successively capacity elements may be progressively smaller, thus giving the same series capacity effect. In a similar manner instead of closer spacing of the shunt inductance elements, the shunt inductance elements may be uniformly spaced and their reactances may be progressively dimished in magnitude.

A desirable form of loaded antennæ is shown in Figure 14 in which the two antennæ 31 and 32, which may be either straight or laterally curved according to the arrangement of Figures 10 or 11, are arranged with corresponding points equidistantly spaced. A source 33 supplies energy to both these antennæ over parallel circuits one of which includes a phase changing device 34. This serves, as in the arrangement of Figure 10, to maintain the energies emitted from corresponding points of the two antennæ at the proper relative phases such that the energy radiated from one antenna will neutralize that radiated from the other in one direction. Each antenna comprises both series capacity and shunt inductance loading, thus combining the arrangement of Figures 2 and 4. The antennæ are progressively varied in height from the source to their remote terminals in order to maintain constant the energy radiated per unit length. Each antenna terminates in an impedance element Z which is designed to absorb the residual unradiated energy reaching the remote terminal.

Figure 15 illustrates a section of an antenna circuit loaded for waves of two different frequencies. L_2 and C_2 indicate respective series inductance including the natural inductance of the circuit and series capacity which together give a capacity reactance at one of the desired frequencies. The shunt path L_3 C_3 C_4 does not affect current of this desired frequency, since L_3 and C_3 constitute an antiresonant loop having substantially infinite impedance at that one frequency. The shunt path may, therefore, be regarded as open for the frequency considered. For current of a second frequency, the path L_3 C_3 is conductive and the net reactance of the whole unit at this frequency may be varied by varying C_4 so as to give any reactance desired for the record frequency current. Of course, an additional shunt path such as L_3 C_3 C_4 could be used for another frequency by shunting such a path about condenser C_4 and including in it a tuned loop or antiresonant circuit to exclude current of the second frequency. In this manner, the number of different frequency currents may be increased as much as desired.

Figure 16 represents a circuit having two

degrees of freedom and which can be adjusted to give the same desired reactances as are given by the arrangement of Fig. 15. This circuit may accordingly replace that of Fig. 15. Its exact adjustment is, however, considerably more difficult.

Figure 17 illustrates an adaptation of the principle of Figure 15 applied to shunt inductance loading. L_s represents a unit shunt loading inductance designed in accordance with the principles previously laid down for currents of one given frequency. The antiresonant loop 35 tuned to this one frequency effectively cuts off the other shunt paths for such currents. The loop 35 admits currents of the second frequency and a variable inductance L_4 permits the network L_s, 35, L_s to give the proper inductive reactance for the second frequency current. Loop 36 in the third path is antiresonant to and effectively excludes currents of the second given frequency for which variable inductance L_4 provides the desired reactance. It conducts a third frequency for which L_4 together with the rest of the network may determine the desired reactance.

Figure 18 illustrates a receiving system with progressively changing loading elements. The conventional receiving element is coupled to the antenna in the ordinary manner and is preferably designed to introduce therein the proper terminating resistance to avoid reflection loss in accordance with the principle previously stated.

Figure 19 shows a multiplex transmitting system equipped with three carrier wave sources and an antenna loaded in the manner of Figure 17. Transmitting keys are associated with two of the sources and a microphone with the third, but it is to be understood that these are merely representative of any desired arrangements for modification of the carrier waves.

Throughout the specification the various features of the invention have been explained from the standpoint of radiation at a transmission station. The principles of wave absorption are in general the same as those of wave radiation. It is, therefore, to be understood that the various features of the invention are equally applicable to receiving systems and the various circuit diagrams may each be considered as representations of a receiving system with the simple substitution of receiving apparatus for the carrier wave source.

In the appended claims the transfer of energy either by radiation from an antenna to the ether or by absorption from the ether to the antenna is analogous to the transfer of energy between media of different characteristics. In telephone parlance the term "transducing" is commonly used to describe generally a transfer of energy without limitation as to the nature of the transfer. Wherever this term occurs in the appended claims, it will be understood that it is intended to be generic both to radiation and absorption of wave energy as well as to the transfer generally of energy from a medium of certain characteristics to media of different characteristics.

What is claimed is:

1. A method of directive radio transmission, utilizing a source of carrier waves and a linear radiating conductor connected therewith, which comprises the steps of radiating a portion of the waves from said source into space, transmitting another portion of said waves along the conductor, absorbing a portion of the energy thus transmitted at points in the conductor, radiating the absorbed energy from said points and preventing reflection of the unabsorbed transmitted waves at the remote terminal.

2. The method of wave transmission which comprises radiating from a conductor very long with respect to the wave length of the radiating energy an amount of energy per unit length of said conductor substantially uniform throughout the entire length of said conductor.

3. The method which comprises propagating an electric wave along a linear conductor at a wave propagation velocity exceeding that of light and radiating a substantially uniform amount of wave energy from each unit length of said conductor.

4. The method of directive radio transmission, utilizing a conducting element, which comprises propagating said waves along the conductor, causing the propagated velocity to differ in a systematic manner at different points in said conducting element, absorbing a portion of the energy from the wave propagated thereacross at each element of the conductor, and radiating said absorbed energy.

5. The method of directive transmission comprising propagating waves along a conductor at a velocity exceeding that of light and progressively varying the velocity of propagation throughout the length of the conductor.

6. The method of electric wave transmission, using a long conductor, which comprises supplying periodic energy to said conductor and propagating it at progressively increasing velocities throughout the length of the conductor.

7. A loaded circuit having loading reactances progressively varying in magnitude throughout its length so as to vary the wave propagation velocity for waves of a given frequency.

8. A directive transmitting antenna comprising a loaded circuit having its loading constants so adjusted that waves of a given frequency are propagated thereover at a velocity exceeding that of light and a termi-

nating impedance connected thereto for absorbing, without reflection, energy transmitted to said impedance.

9. In a directive radio transmitting system in combination, a transmitting antenna, a source associated therewith for supplying continuous waves to said antenna and a terminating element connected to said antenna for preventing reflection of said waves back toward said source.

10. In a directive radio transmitting system in combination, a transmitting antenna, means for supplying periodic energy thereto, said antenna being so loaded as to transmit the wave form of said energy at a velocity exceeding that of light and a terminating impedance connected to said antenna to prevent retransmission of energy back to said means.

11. In combination, a long horizontal antenna, a source of periodic energy associated therewith for supplying energy thereto, and means for causing said antenna to radiate a uniform quantity of the supplied energy per unit length of the antenna.

12. In combination, a long antenna, means connected to one terminal thereof for supplying periodic energy thereto, and means for changing the radiation resistance of said antenna progressively throughout its length so as to keep the quantity of radiated energy constant per unit length.

13. An antenna, means for supplying a periodic wave of a given frequency thereto and means for progressively varying the wave propagation velocity of said antenna whereby the radiated energy of said wave may be directively focussed upon a distant point.

14. A conductor curved upwardly throughout its length, and means for so loading said conductor as to cause it to radiate energy directively throughout its length.

15. A method of directive radio transmission, utilizing a source of carrier waves and a linear radiating conductor connected therewith, which comprises the steps of radiating a portion of the waves of said source into space, transmitting another portion of said waves along the conductor, absorbing a portion of the energy thus transmitted at points in the conductor, radiating the absorbed energy from said points, neutralizing the radiation from said conductor in one direction, and preventing deflection of the unabsorbed transmitted waves at the remote terminal.

16. The method which comprises propagating an electric wave along a linear conductor at a wave propagation velocity exceeding that of light, radiating a substantially uniform amount of wave energy from each unit length of said conductor, and neutralizing the radiation from said conductor in one direction.

17. The method of directive radio transmission, utilizing a conducting element, which comprises propagating said waves along the conducting element, causing the propagated velocity to differ in a systematic manner at different points in said conducting element, absorbing a portion of the energy from the wave propagated thereacross at each element of the conducting element, radiating said absorbed energy, and neutralizing the radiation from said conducting element in one direction.

18. The method of directive transmission comprising propagating waves along a conductor at a velocity exceeding that of light, progressively varying the velocity of propagation throughout the length of the conductor, and neutralizing the radiation from the conductor in one direction.

19. A loaded circuit having loading reactances progressively varying in magnitude throughout its length so as to vary the wave propagation velocity for waves of a given frequency, whereby said circuit tends to radiate directively in lateral directions, and means for neutralizing the radiation in one of said directions.

20. A directive transmitting antenna comprising a loaded circuit having its loading constants so adjusted that waves of a given frequency are propagated thereover at a velocity exceeding that of light, whereby said circuit tends to radiate directively in lateral directions, a terminating impedance connected to said circuit for absorbing, without reflection, energy transmitted to said impedance, and means for neutralizing the radiation in one of said directions.

21. A loaded circuit having loading reactances progressively varying in magnitude through its length so as to vary the wave propagation velocity for waves of a given frequency, whereby said circuit tends to radiate directively in lateral directions, and means for neutralizing the radiation in one of said directions, said means comprising a second loaded circuit arranged in parallel with the first loaded circuit.

22. In combination, a source of energy and connected thereto a loaded circuit having loading reactances progressively varying in magnitude throughout its length so as to vary the wave propagation velocity for waves of a given frequency, whereby said loaded circuit tends to radiate directively in lateral directions, and means for neutralizing the radiation in one of said directions, said means comprising a second loaded circuit arranged in parallel with the first loaded circuit with respect to said source and including a phase shifting means, whereby the energies supplied to said loaded circuits have a desired phase difference.

In witness whereof, I hereunto subscribe my name this 13th day of May A. D., 1921.

RAYMOND A. HEISING.

TRANSLATION DIVISION NO. BY RS WORDS FOR ITT Pat. Dept.

French Patent No. 593,570.

IMPROVEMENTS IN DIRECTIONAL ANTENNAE

Lucien Levy, a resident of France (Seine).

Applied for April 29, 1924, at 4:30 P.M., in Paris.

Granted May 30, 1925. -- Published August 26, 1925.

(Patent the granting of which has been held up in compliance with article 11, # 7, of the law of July 5, 1844, revised by the law of April 7, 1902.)

The general type of antenna used heretofore consists of one or a plurality of wires arranged in space and connected to one pole and one or a plurality of high frequency generators whose other pole is connected to the ground or to one or a plurality of wires constituting a counterpoise. In certain cases, the wires of the antenna or those of the counterpoise are connected together by cross wires which consist of providing equipotential points.

Under these conditions, the antenna radiates a vertical electric field which is accompanied in its propagation by currents on the ground, which cause power losses.

It has been suggested, in order to prevent such losses, that the power be radiated by means of vertical antennae of several wave lengths; under these conditions, the antenna does not radiate power on the ground surface but radiates in the space comprised between two conical surfaces whose angle at the top is less than 90 degrees and whose axis is the antenna.

In the case of ordinary antennae, if diagrams are drawn with the current in the antenna as the ordinate and the wires as the abscissa, one will obtain either a curve or a surface with a single curvature.

The present application refers to improvements in antennae intended to obtain a more intense radiation of radiant energy towards the receiving pole and to favor the propagation of this energy with a minimum of loss.

With this object in mind, the present invention contemplates the use of radiating surfaces (planes for example) in which the distribution of the current is such that, if we take the current at each point as the ordinate, double curvature surfaces will be obtained. In other words, the surface being fed at high frequency at two points, the current is subject to a double propagation along coming to two perpendicular axes.

Thanks to this double propagation, the directional effect of the antenna is much greater and, instead of obtaining a toroidal radiating surface as with ordinary antennae, one obtains only a pencil form radiation.

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Further, the invention also contemplates the use of sending antennae radiating a horizontal electric field instead of a vertical electric field, with the purpose of obtaining a greater directional effect and smaller losses during propagation.

An extremely important point, necessitating the use of a horizontal electric field, is that long distance transmission of short waves seems to be effected by reflection on the Heaviside layer. Now, it is easy to see that a horizontal electric field polarized wave will be reflected without loss of energy on a horizontal conductor plane, while on the contrary a vertical electric field wave is liable to fall under the Brewster incidence and, in that case, there will be no reflected energy. It is therefore logical to think that feding phenomena will be non-existent for horizontal electric field waves. Finally, it is desirable to point out that the parasites are very weak in a horizontal framework, for which reason horizontal electric field waves should be particularly suitable for antiparasite reception.

Horizontal antennae have already been used, but these antennae have been employed for long wave lengths and relatively very close to the ground. The invention envisages, on the contrary, horizontal antennae for the transmission of short waves and placed at a height representing an important fraction of the wave length transmitted (one quarter wave length for example). Thanks to this height and to the horizontal character of the electric field, the losses in the neighborhood of the electric antenna are greatly reduced.

It is extremely important to raise the horizontal antennae to a suitable height, greater than 1/8 of the wave length transmitted. In effect, the conductive ground effect is to give an image of the antenna. If the antenna is close to the ground this image, which radiates an inverse field to the one radiated by the antenna, partially neutralizes the effect at a distance from the antenna. This objectionable feature is avoided when the height of the horizontal antenna is comprised between $\frac{1}{8}$ of the wave length $\frac{\lambda}{4}$ and $\frac{3}{8}\lambda$. In this case, in effect, the radiations of the image and of the antenna combine. It is easy to figure also the effects of inclination on the horizontal plane of the maximum energy in the vertical plane of maximum radiation, effects which are produced owing to the combination at a distance of the radiation of the antenna and of its image whose currents are out of phase by a quantity which depends upon the height at which the horizontal antenna is arranged. It will be noted that a counterpoise, consisting of a wire arranged on the surface and in or out of harmony, will permit of changing at will the phase of the currents radiated by the image and the inclination of the pencil of maximum energy.

The radiation is effected in these horizontal antennae laterally and perpendicularly to the direction of the antenna when the latter is a single-propagation antenna and according to one of the two axes of propagation of the currents on the surface of radiation when a double-propagation radiating surface is used.

Fig. 1 represents an interpretation of a horizontal antenna built according to the invention.

This antenna consists of a network of horizontal wires 1 and 2 supported between the towers 3 and 4 by swingle-trees 6 and 8 insulated from the live wires by insulators 5 and 7. Wires 1 and 2 are connected together by insulator chains 14. A high frequency generator 11 is connected, by two-wire line 9, 10, to the

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antenna at 12 and 13.

Operation. While at first sight this antenna recalls the T vertical antenna, it is totally different.

Wires 9 and 10 of the supply line are traversed in opposite direction by the high frequency currents according to the arrows 16 and 17 and, consequently, the vertical radiation of the line 9 and 10 is zero.

Only portion 16-17 radiates, laterally and according to the direction 18, a horizontal electric field h and a vertical magnetic field H.

The reception of these horizontal electric field waves may be effected by means of a horizontal antenna arranged parallel to the field h and which may be either elevated or at the ground level. Thanks to the inclination of the magnetic field in the direction of propagation, it is also possible to use vertical or horizontal antennae directed in a direction perpendicular to the preceding direction.

If a receiving loop antenna is used, it should generally be placed in a horizontal plane, but reception will also be possible with a vertical loop antenna placed perpendicular to the direction from the transmitter to the receiver.

Fig. 2 is a diagram showing the distribution of the currents in the antenna. There has been provided at each point of wires 9, 10, 1 and 2 a perpendicular proportional to the current at this point at a given moment.

It will be seen that line 9-10 is a half-wave line and that the wires 1 and 2 are quarter wave length. Other distributions might also have been chosen. Any desired distribution may be obtained by combining with the antenna elements of artificial lines as provided for in Levy patent No. 506897, of October 1, 1918.

In particular, one may avoid any distribution by forming each conductor 9 and 10 of a series of elementary wires that will successively present the distributed capacity of the one to the other.

Fig. 3 represents a horizontal radiating surface for the transmission of horizontal field waves in pencil form in a preferred direction inclined on the horizontal and Fig. 4 is a diagram showing the distribution of the currents in one of the networks of this arrangement.

This surface is presented in perspective and radiates its energy in the direction of arrow 19 with a maximum radiation in the vertical plane of symmetry 20.

The radiating surface is supported schematically by the four insulators 5, 5 and 7, 7 on the four towers 3, 3 and 4, 4. The generator 11 supplies the high frequency current at 12 and 13. The high frequency currents propagate on this surface in such a way that one may consider that the half-wave system 16, 17 propagates from the front to the back of the figure. The dimensions of the surface from front to rear are such that the propagation from front to rear comprises several quarter wave lengths. One has therefore a double stationary system, one of half wave length parallel to arrows 16, 17, and the other parallel to arrows 21 and 22 and of several quarter wave lengths.

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Thanks to the propagation 18, 17, the radiation energy is concentrated in plane 20 and, thanks to the propagation in the perpendicular direction, it is limited to a pencil inclined on the horizontal. It is easy moreover to change the inclination of the pencil by changing the distribution parallel to plane 20, for example by inserting choke coils or capacities placed on the ground level and connected to the surface by parallel conductors at 9 and at 10.

It should be pointed out that radiating surfaces may comprise a larger number of main axes according to which the propagation is effected, particularly one can envisage three axes forming a trihedral, and that one may thus obtain radiating beams as loose as desired.

Likewise, these surfaces may be arranged in all directions and radiate an electric field having any inclination; they may also be used as a reflector.

The use of the devices described applies to all waves, but it should be pointed out that the results are most particularly interesting for short waves less than 1,000 meters long, particularly for waves of 100 and 200 meters.

The radiating networks could also consist of metallic tubes or any other conductor.

SUMMARY

A method for long distance transmission of Hertzian radiant energy, characterized by:

1. The transmission of horizontal electric field waves to favor the reflection without loss on the Heaviside layer and on the ground and the propagation through space.

2. The energy transmitted presents a maximum in the vertical plane perpendicular to the axis of the radiator.

3. The energy is transmitted in the form of an inclined pencil accepting as the plane of symmetry the vertical plane perpendicular to the axis of the radiator.

4. The invention also covers the incorperations of the method in which:

a) The single-propagation antenna consists of two horizontal wires (or two networks) connected respectively to the two poles of a high frequency generator.

b) The antenna is placed at a height comprised between $\frac{\lambda}{8}$ and $\frac{5\lambda}{8}$ (λ = wave length transmitted).

c) The two poles of the generator are connected respectively to each of the networks.

d) Each of the networks is approximately 1/4 wave length long.

e) The horizontal antenna having a single axis of propagation radiates the energy perpendicular to its axis.

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f) The antenna having two axes of propagation consists of two horizontal rectangular networks fed by the generator at two contiguous peaks of the networks.

g) The antenna having two axes of propagation has one of its propagations half wave and the other of several quarter wave lengths.

h) The antenna having two axes of propagation radiates its energy perpendicular to the axis of half-wave propagation and in the direction going from the supply point of the surface towards the end of the radiating surface.

i) The loop receiving antennae for horizontal electric field waves consist of horizontal loops or of vertical loops perpendicular to the transmitter-receiver direction.

j) The application of these devices for transmission and reception is envisaged particularly with short waves of less than 1,000 meter wave length.

k) The arrangement of a counterpoise parallel to the antenna on the ground surface is realized in or out of harmony with the counterpoise.

L. LEVY.

A. Mathieu,
Attorney. AA/18

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Fig. 1



Fig. 3

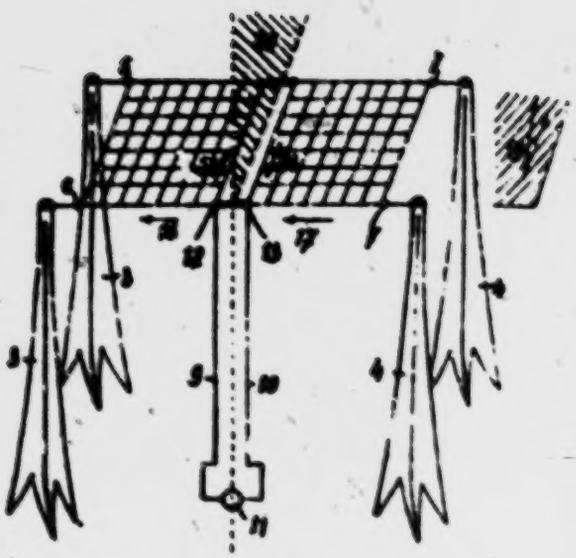


Fig. 2



Fig. 4



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First Addition t. French Patent No. 593,570. No. 30,769

IMPROVEMENTS IN DIRECTIONAL ANTENNAE

M. Lucien Levy, a resident of France (Seine).

(Main patent taken out April 29, 1924.)

Applied for April 28, 1925, at 4:53 P.M., in Paris.

Granted June 1, 1926. -- Published August 23, 1926.

(Certificate of Addition the granting of which has been held up in compliance with article 11, § 7, of the law of July 5, 1844, revised by the law of April 7, 1902.)

The present addition refers to changes and improvements made in the antenna devices forming the subject of the main patent.

In the first place, it is desirable to point out that it is possible, instead of adopting the arrangements described in the main patent, to conceive of different variations which may offer advantages in certain cases, particularly where it is desired to radiate energy in a given direction.

For example, wires 1 and 2 in the arrangement shown in Fig. 1 of the main patent may, instead of being parallel to the same direction, form between themselves any angle and particularly they may be perpendicular.

Fig. 1 of the accompanying drawing shows an antenna whose radiators 1 and 2 situated on the same horizontal plane form between themselves an angle of less than 180° (the same reference numbers have been used as in the main patent to designate corresponding parts).

Likewise, the radiating surfaces of Fig. 3 in the main patent are not necessarily constituted by a lattice. Fig. 2 shows a variation of the antenna, in which the radiating networks are formed solely by the wires 27, 23, 24 and 28, 25, 26.

Finally, Fig. 3 shows an antenna device intermediate between the two types described above and consisting of two angular networks 12, 5, 5 and 13, 7, 7, themselves forming an angle and supplied at points 18, 13 by generator 11.

All these devices are characterized by the arrangement of radiating elements, generally horizontal, carrying high frequency currents at a sufficient height above the ground (more than a quarter wave length), the two poles of the high frequency current generator being connected respectively each to one or more radiating elements.

But it is not necessary that the divers horizontal radiating elements be fed by voltages in phase opposition, and an improvement of the invention consists in

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feeding these elements by voltages out of phase with respect to each other any quantity, constant or variable in time.

As a characteristic example of this improvement, Fig. 4 shows an antenna that permits of feeding two horizontal radiating elements by currents of any phase displacement.

In this figure, elements 29, 30, 31, 32, 33, 34, 35 correspond to elements 5, 9, 12, 13, 11. 1, 2 of the horizontal antenna 1, 2.

Generator 33 is out of phase 90° with respect to generator 11. These two generators have been shown here separately only for the simplicity of explanation, but in general they will not be different and will be replaced in an actual installation for example by two circuits of a vacuum tube installation (having one or more tubes), as described particularly in Levy patent No. 524,040.

If the two radiating elements are, for example, perpendicular and if the voltages applied to these elements are of the same frequency and out of phase 90°, an horizontal electric field will be produced, rotating at high frequency, whose radiating effects are most peculiar. This field is a circularly polarized field; its frequency of rotation is equal to the frequency F of the currents flowing over the radiators. The directional effect of the waves disappears.

However, if the radiators carry currents of the same frequency F but out of phase less than 90°, an elliptically polarized field will be obtained.

Finally, if the two radiators carry currents of equal amplitude and of frequencies F_1 and F_2—the currents of the second being out of phase 90°—, the superposition of two rotating fields will be obtained. If $\omega_1 = 2\pi F_1$ and $\omega_2 = 2\pi F_2$, the total field H is equal to $H_0 \sin \omega_1 t + H_0 \sin \omega_2 t$, hence

$$H = 2 \sin \frac{\omega_1 + \omega_2}{2} t \cos \frac{\omega_1 - \omega_2}{2} t;$$ it is all as if the field of frequency $\frac{\omega_1 + \omega_2}{2}$ rotated at a speed of $\frac{\omega_1 - \omega_2}{2}$ t on an horizontal plane. The same applies to the radiated field and at any point in space a field will be obtained rotating at a speed of $\frac{\omega_1 - \omega_2}{2}$, which is less than the pulverization $2\pi F$ of the emission. For example, the fictitious radiating electric field and the receiving fields can be made to rotate at a speed of the order of 10,000 revolutions or even 1,000 revolutions per second.

It can also be arranged that the rotation of the fictitious radiating field is produced by the frequency modulation of one of the generators and, in this case, a new method of radio telephony can be obtained.

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By means of the new method described above, therefore, an horizontal electric field rotating at a speed comprised between 2 NY and 0 can be obtained at the receiving station.

It is hardly necessary to emphasize the importance of this result, which permits of a veritable synchronization between the sending station and the receiving station and an absolutely sure elimination of parasites which in no way present themselves in the form of such rotating fields.

But the invention, as concerns the use of rotating hertzian fields, is not limited to the radiation of electric fields rotating on an horizontal plane; it immediately generalizes into fields rotating in space and particularizes also into fields rotating on vertical planes and even into fixed fields in any position in space.

For example, a vertical antenna and an horizontal antenna carrying currents out of phase 90 degrees can be combined, with the purpose of obtaining energy radiation perpendicular to the plane of the two antennae, in the form of an electric field rotating on a plane parallel to the plane of the two antennae.

In the arrangement shown in Fig. 5, where the currents in the horizontal antenna and the vertical antenna are in phase, instead of being out of phase 90°, or in the equivalent case where an antenna inclined with respect to the ground is used for transmission, an electric field inclined with respect to the ground is transmitted. It is to be remarked that this field enables one to tell, when in front of a vehicle, whether such vehicle is moving towards or away from one. Let us assume that, by convention, it is agreed that, when one is in front of the front part of a vehicle, one will see the field rise from left to right. If the vehicle turns around to move away from the observer, the latter will see the field return and consequently rise from right to left and become perpendicular to its initial position.

A means is therefore available that may be used particularly to prevent collisions in the fog between vehicles or ships. In this case, in the front part of all vehicles would be installed sets sending waves inclined 45°, equipped with receivers of waves perpendicular to the said direction of 45°, not affected therefore by local emissions and sensitive to emissions from dangerous vehicles.

Finally, it should be remarked that polarized light waves being in all respects identical to hertzian waves, the invention provides a means of preventing the blinding of headlight-equipped vehicles by one another. The wave sender would then consist of a headlight (beacon) sending polarized light at 45° and the operator (driver) of the vehicle whose eyes constitute the receiver would be equipped with analyzing glasses (tourmaline or nicol), allowing the passage only of waves polarized parallel to his own emission and opposing the passage of light waves coming from the blinding headlight.

It is desirable to point out in connection with rotating fields that a new field is opened to the art and that the use of these fields should make possible a better knowledge of the Heaviside layer and a better efficiency in radioelectric circuits. This layer, in effect, should not act merely as a simple metallic reflector and must present phenomena comparable to the double refraction in optics. It is possible even that phenomena may be obtained comparable to the rotation of the plane of polarization by penetration in the layer and the reflection that

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should occur.

It is possible therefore that there be, after reflection on the Heaviside layer, either rotation of the plane of maximum radiation or interest in employing circularly polarized waves, either [illegible]. It is possible, finally, that there be produced an elliptic polarization of waves which are reflected on the said dielectric and conductive layer.

Be that as it may, horizontal electric field waves must cause phenomena much more simple and particularly permit of obtaining the means of transmitting to any distance, which is not possible with short waves polarized vertically for certain medium distances, the cause wherefor must certainly be the impossibility of reflecting any notable energy under the Brewster angle.

The first trials made with horizontal waves have given considerable ranges, even during the daytime and on wave lengths of the order of 80 m., with the disappearence of the fading effect. The radiation seems to take place, not only in the direction foreseen, but also in the perpendicular direction, which might be explained by the circular polarization effects mentioned above.

It should be mentioned that the generators feeding the horizontal antennae are assured to be at the ground and connected to the radiating portion of the antenna by a two-wire line. It is evident that the latter is necessary if it is desired to keep the generator on the ground the minimum height of the antenna above the ground being fixed. But if the generator can be brought up to the height of the antenna, the supply line is eliminated. Fig. 5 shows an antenna 1^a, 2^a of this type, installed in an airplane.

Finally, it should be noted that, by combining a vertical electric field emission with an horizontal field emission, it is possible to indicate at any moment to a vehicle its deviation with respect to the correct route. In this case, one uses an antenna of the type shown in Fig. 1 of the main patent and perpendicular to the route to be followed; the magnetic field of the vertical wave should be parallel to the electric field of the horizontal wave and reception is obtained on board the airplane with a vertical loop antenna which should give two perpendicular directions by the maximum position for the correct route. This device is used particularly to locate the entrance to a port in foggy weather.

Fig. 7 shows the arrangement foreseen above of a wave generating station at the height of the antenna, which [illegible] in space. Antenna 1, 2 rests on top of pylon 3, whose height is of the order of a quarter of the wave transmitted or greater than such quarter wave length. This antenna preferably consists of two rigid tubes, arranged on either side of the generator and of the length generally chosen of the order of a quarter wave or half a wave length. Joint 36 permits of directing the antenna according to all the inclinations. If the lengths exceed half (1/2) a wave length, it will suffice to turn back 180° the part of the radiator that would radiate in the direction opposite to the desired direction. Figs. 8 and 9 show radiators of this type, which could replace radiator 1, 2 of Fig. 7.

[illegible]

The addition refers to improvements made in antennae, whereof the distinctive

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tures are as follows:

1. The antenna consists of two conductors situated on an horizontal plane sufficiently high above the ground and that can be connected by a two-wire line to a generator located on the ground.

2. The two conductors can be rectilinear and form an angle between themselves.

3. The radiating surfaces can consist of wire networks.

4. The radiating surfaces can be angularly arranged.

5. The radiating elements can be supplied by voltages out of phase with respect to each other, for example out of phase 90°.

6. The horizontal antenna can be combined with a vertical antenna, the two antennae carrying currents out of phase or in phase.

7. The generator, instead of being arranged on the ground, can be placed at the height of the antenna so as to eliminate the supply line.

The addition likewise covers the application of these improvements either to reveal the direction in which vehicles are moving, on land, in the air or in the water, or to show their deviation with respect to the right course, as also the application of polarized light waves to prevent blinding by headlights.

L. LEVY.

P. Degroote,
Attorney.

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N° 38.798 M. Lévy 3 planches. — Pl. I

Fig. 1

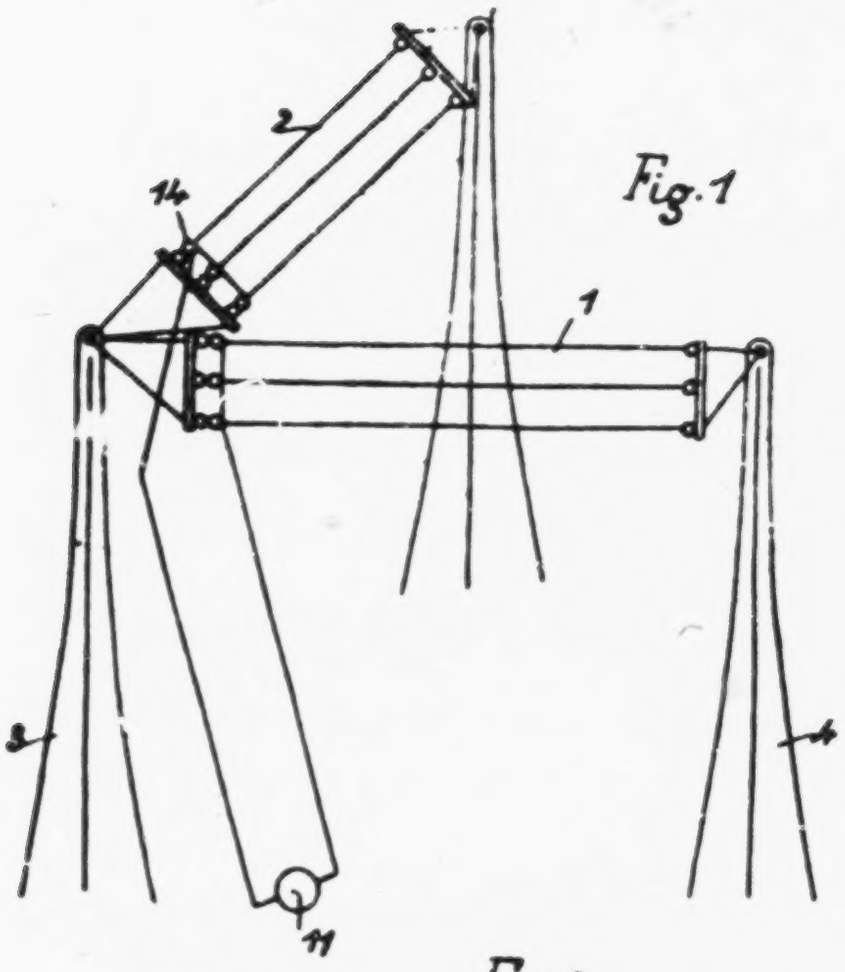
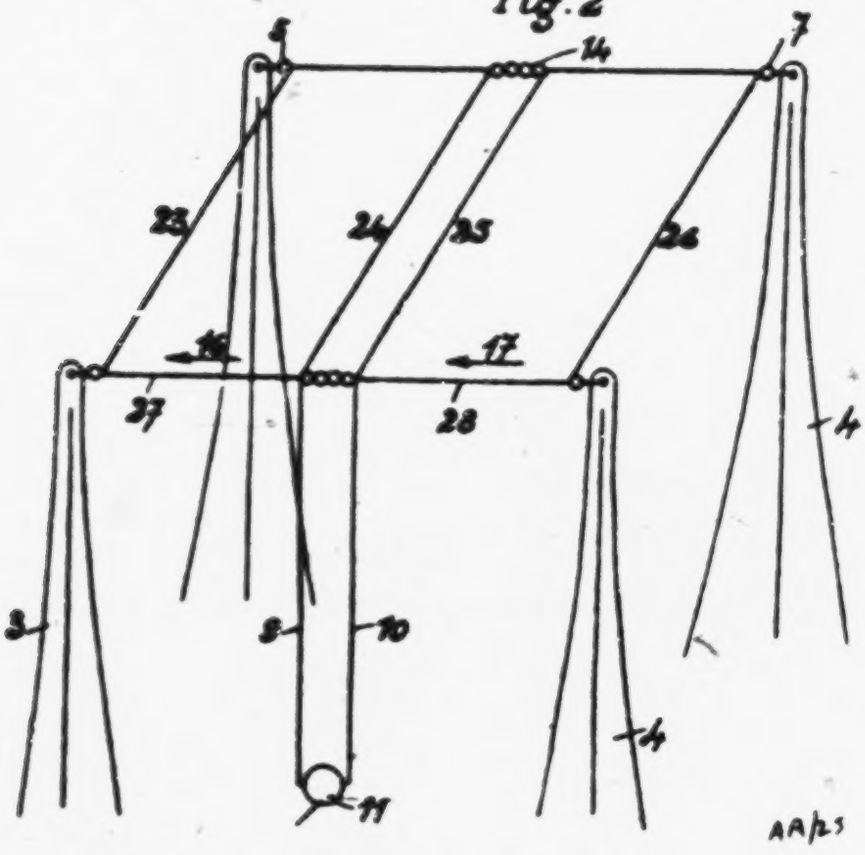


Fig. 2



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Fig.3

Fig.4

Fig.5

Fig.6

Fig.7

Fig.8

Fig.9

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The Official Organ of the A·R·R·L·

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QST is published monthly by The American Radio Relay League, Inc., at Hartford, Conn., U. S. A.
Official organ of the A.R.R.L. and the International Amateur Radio Union

Kenneth B. Warner (Secretary, A.R.R.L.), Editor-in-Chief and Business Manager
F. Chapman Bosley, Managing Editor and Advertising Manager

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Subscription rate in United States and Possessions, Canada, and all countries in the American Postal Union, $2.00 per year; foreign countries, $2.50 per year. Single copies, 25 cents. Foreign postage rate is $1.00 per year. Remittances should be by International money order, draft on bank in U. S. A. or Canada, or by registered mail. Currency should only be sent at sender's risk. Entered as second class matter May 25, 1915, at the post office at Hartford, Connecticut, under the act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized January 25, 1919. Publication delay on publication dates, account of issuance of radio stations provided for above, or temporary discontinuance of same.

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Straightening Out the Antenna

By Benjamin S. Melton*

THE following article is intended to straighten out our ideas on radiating systems in general, to show why a grounded antenna can only be operated on a so-called "odd-harmonic," to suggest that a simple radiating system is probably the best and to show how to get the juice into the antenna in such a way that the antenna will be given a chance to throw it away most efficiently.

In the first place, it will simplify matters if we stop talking of antennae operating on their fundamentals, even or odd harmonics, etc. Such terms, while they may have meaning, tend to confuse our ideas, and prevent us from seeing the true conditions in a given radiating system. The terminology used in this article represents present day commercial practice. It will be seen that this terminology is logical and present a clear mental picture of what happens in the radiating system.[1]

The Possible Antennae

Let us take a certain wave, such as 10 meters, and show some of the possible radiating systems, considering only such systems as are composed of a single conductor, either connected to earth or insulated. We shall see how this wave can be radiated from various antenna systems fulfilling certain conditions.

In the first place, (for resonance) the antenna system must have a physical length which is an integral multiple of a quater wavelength.

Fig. 1 illustrates the various lengths of systems, and also the names of these various lengths. The voltage distribution on these systems is shown also. It will be noticed that the "free" end of any system must have a voltage loop, or peak, as it has a current node at this point. No current can flow to or from a "free" end to ground (neglecting insulator leakage).

It may be seen from Fig. 1 that the systems which are an odd number of quarter waves in length *must be grounded at one end*, as they have current loops (corresponding to voltage nodes) at that end. A current must therefore flow to or from that end to the ground. Furthermore, it may be seen that the systems which are an even number of quarter waves in length *must not be grounded at either end*, as a high voltage

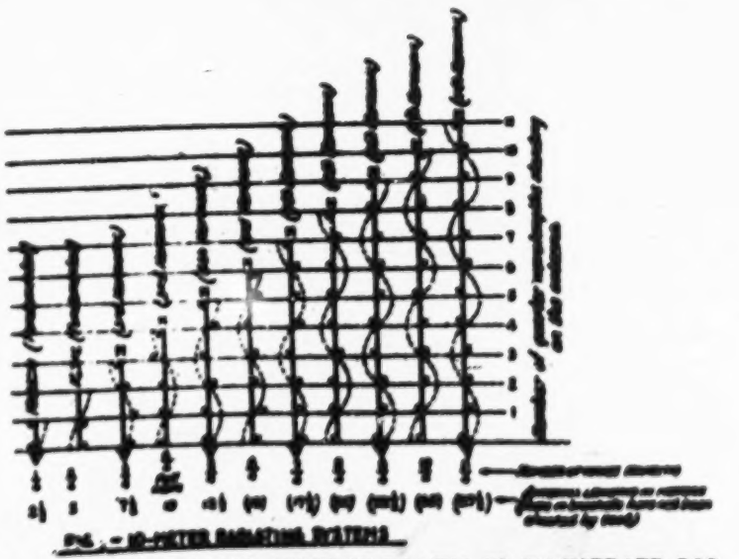


FIG. 1—10-METER RADIATING SYSTEMS

10-METER RADIATING SYSTEMS DRAWN TO ILLUSTRATE POSSIBLE METHODS OF OPERATING BOTH GROUNDED AND UNGROUNDED ANTENNA

The designations at the base of the antennas are those suggested by the author while the ones at the top are in accord with usual amateur practice. Note that the grounded systems can be operated only with an odd number of quarter waves standing in on the antenna while the ungrounded systems can be operated with either an odd or an even number of quarter waves standing.

The dotted lines show the voltage distribution. The points "O" are the voltage nodes (current loops) at which "current feed" can be used to best advantage. The points "V" are the voltage loops (current nodes). Voltage feed must be applied at the points "V" or at least not too far from them.

While the antennae shown are vertical it is possible to operate the ungrounded ones in any position. Both the grounded and the ungrounded ones may be bent instead of straight.

---

* General Electric Co., Schenectady, N. Y.

1 There is room for argument here. When we refer to the oscillating circuits inside the station it is essentially necessary to speak of the harmonics that are present in them. It seems exactly as reasonable to refer to the harmonics of the open circuit outside the station—and save out of terms answers for both purposes.—Tech. Ed.

2 Is it not surprising that this can be said without starting a violent argument. A few years ago when spark coils were universal almost all antennas were made small for the wavelength and operated with loading coils. This gave very large antenna currents and there are many old texts and governmental publications that advise operating with an antenna of the proper size to give the largest antenna current. Radiation was perhaps the most active consideration. Just this belief and gradually we have gone over to antennae large enough to be operated unloaded or even to be operated at a harmonic—a statement I am unfortunately not able to put into the supported terminology of the author.—Tech. Ed.

from a point to ground cannot exist when the point is grounded.

Horizontal Antennae

Remember, also, that these systems can be made horizontally[1], except that in such a case it is not possible to ground one end *definitely*. Any wire run from one end of



FIG. 2

CURRENT-FEED SYSTEMS

A. Feed line with transformer at the antenna. See text for construction.

B. Feed line without transformer at antenna. Both ends should have a transformer at the ground end of the line.

... antenna to the ground would form part of the radiating system itself. Thus (for horizontal antennae) we are limited to systems an even number of quarter waves long.

Bent Antennae

So far we have talked about straight antennas entirely. The straight (or linear) antenna was first used by Hertz who worked entirely with vertical ungrounded systems which were put in all sorts of positions—vertical, horizontal and slantwise. Marconi probably introduced the use of the ground connection—though there is some argument about this. These are the systems marked "Hertz" and "Marconi" in Figure 1.

Now these systems become pretty large if we are to work at any but the shortest wavelengths and therefore with wavelengths above 40 meters we usually have antennas which are bent over to keep from using large and expensive towers. If such an antenna works with a ground ... it is a modification of Marconi's ... inal scheme. It may operate with a ¼ wave standing on it or may operate in any of the ways which have an ODD number of quarter waves on the antenna—in other words it can work in any of the ways marked "M" in figure 1.

Bent Antennae with Counterpoise

If a bent antenna is worked with a counterpoise it is hard to say what type we shall classify it under. It is a double-ended affair like the Hertz antenna, yet one end is connected to the earth, (thru the counterpoise-earth capacity) which is a resemblance of the Marconi scheme. If the counterpoise is large and near the earth it is almost a a Marconi-type antenna but if the counterpoise is small and far above the ground the thing is almost a Hertz-type antenna. Some German writers get around this difficulty by referring to bent antenna-counterpoise systems as "Braun antennae" because Braun seems to have put them into commercial use first.

The name is not so important as the method of operation. Unfortunately this is not a thing about which one can make a simple statement as in the previous cases. If the counterpoise is very large it will act (as mentioned before) as a series condenser in a grounded system and the antenna will operate with an ODD number of quarter waves standing on it, just as shown for the "M" antennas in Fig. 1. Such counterpoises are unusual in amateur work although there have been some—for instance the great wheel-counterpoise at 8AQO in Canenovia, New York. The voltage-to-ground was very small with that C. P., even when several kilowatt were being fed to the antenna. The C. P. could be touched without danger.

With the more usual amateur counterpoises the capacity to-ground is very small and the system operates with an EVEN number of quarter-waves standing on it—there is voltage at both the antenna top and the C. P. ends. This means that the system works in one of the various ways labeled "H" in Figure 1.

The waves on these radiating systems are known as "standing waves." This simply means that points of zero potential (nodes) and points of maximum potential (loops) do not move along the wire in the direction of its length.

Feeding

Suppose now that we wish to excite any of these systems. There are two general methods of excitation or "feed." The first is "current feed," *usually* through electro magnetic (inductive) coupling. The second is "voltage feed," *usually* by means of electrostatic (capacity) coupling. Either of these methods may be used with any radiating system provided the current feed is not attempted at a current node, nor the voltage feed at a voltage node. See Fig. 1.

It is not necessary to use a voltage feed exactly at a voltage loop, nor a current feed at a current loop, though it is usually more convenient, and tends to give less trouble in practice, especially in the case of the current feed.

To illustrate the two types of feeding we shall consider the half-wave antenna, in a

AA/1

1. For some unknown reason amateurs have begun to call the horizontal linear antenna the "Hertzian antenna". Hertz's antennae were quite as often vertical as they were horizontal. "Hertzian" had best be kept to mean a straight antenna without much (if any) loading elsewhere of the quarter than the thing may have.—Tech. Ed.

horizontal position, and more than about one half wavelength above the ground.

Current Feed

First we shall consider current feed. There are two methods in this case, as shown in Fig. 2, though they amount to the same thing. The advantage of the second arrangement is that the antenna can be tuned somewhat from the station end of the transmission line, though such tuning shifts the voltage nodes (the single node has been split in two by the introduction of the transmission line) either out along the antenna, or down on the transmission line. It may be seen that this arrangement becomes a partial voltage feed when the voltage nodes are shifted.

Voltage Feed

We shall now consider voltage feed. One method of obtaining this is shown in Fig. 3. Though a small capacity is shown for this method, and inductance may be substituted, or the wire leading from the oscillating tuned circuit may be continuous. The requirement for correct operation is simply that there be a voltage loop or peak at the end of the feed wire. The meter in the antenna will be at a maximum when this is so. Sometimes the feed wire happens to be of the correct length to build up such a peak, sometimes an inductance or capacity is required to put the voltage loop at the correct point. It may be seen that if the feed wire itself is of the correct length for a voltage loop at its top, it will form part of the radiating system.

The single feed wire need not necessarily be connected to the end of the antenna, but instead may be connected almost anywhere between the end and the middle, although at any point between the end and the middle it forms a combination current and voltage feed.

The straight half-wave antenna is generally admitted to be the most efficient *radiator*, but this does not necessarily mean that it is the *best antenna* to send the energy over *long distances*, as it may not send it at the proper angle for best results. From consideration of *theoretical* angles of propagation, and from *very meager* experimental information, it is my personal *opinion* that the full-wave vertical antenna may be one of the best radiating systems for short waves.

Transmission lines used to feed antennae have many advantages, and should be used more generally than they are. Put the antenna where it will be away from other conductors, place the set where convenient, and run a transmission line of any length necessary between the two. As long as the line is well insulated and the wires not spaced too far apart (four to ten inches is O. K.), the line will not lose much energy through conductive leaks or radiation.

When coupling into an antenna by means of a transformer as shown in Fig 2A, the ratio of the primary turns to secondary turns should be the square root of the ratio of the surge impedance of the line to the resistance of the antenna, provided the primary and secondary are very closely coupled. (Unity coupling to make this statement exactly correct). The surge impedance of a no-loss line is equal to $\sqrt{\frac{L}{C}}$, and does not change much for any ordinary line, being on the order of 600 ohms. The resistance of a straight half-wave antenna unloaded is about 100 ohms, provided the antenna is some distance from the earth and other conductors, and has no large lumped inductance or capacity. Hence a good transformer turns-ratio to start with is about 2½ to 1. That is, for one turn in the antenna, use between two and two and one-half turns in the end of the transmission line, provided all turns are about the same diameter. The coupling between primary and secondary should be as close as can be obtained[1].

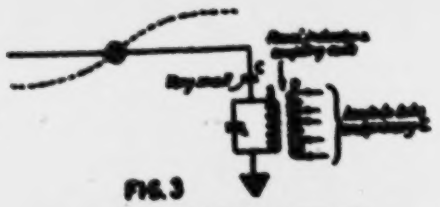


FIG. 3

A VOLTAGE-FEED SYSTEM

While the feeder is shown connected at the voltage loop (see Fig. 1) it can be connected at a point nearer the node and this is frequently done in practice. In this figure and figure 2 the antennae may be vertical, horizontal or sloping.

1. Do not confuse this with the transformer at the station end of the line. Excessively close coupling at that point will result in the usual interference difficulties.—Tech. Ed.

Strays

We desire to call to the attention of the experimentally inclined readers of QST a magazine which they, by all means, should be seeing, and that is *Experimental Wireless and the Wireless Engineer*, published at Dorset House, Tudor Street, London, E. C. 4, England. This magazine is always chock-full of very interesting information both of a theoretical and a practical nature. It is the official organ of the Radio Society of Great Britain and is something you really should not be missing. Incidentally it costs only 15 shillings a year and can be obtained from the above address.

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RADIO COMMUNICATION

THEORY AND METHODS

WITH AN APPENDIX
ON
TRANSMISSION OVER WIRES

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FIRST EDITION
THIRD IMPRESSION

McGRAW-HILL BOOK COMPANY, Inc.
239 WEST 39TH STREET, NEW YORK

LONDON: HILL PUBLISHING CO
6 & 8 BOUVERIE ST., E.
1917

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station whose signals are loudest at X. If a second group of directive transmitters are at B the location of X is of course determined by simple triangulation.

Directive Transmitters.—The simplest form of directive transmitter consists of two antennæ A_1 and A_2 separated by a distance d as in Fig. 113. The currents in the two antennæ are from the same source but are out of phase. Let the current in A_1 be $Ie^{j\omega t}$ and that in A_2 be $Ie^{j(\omega t+\theta)}$. At some point p_1 distant X along the line A_1A_2 the effect[1] of antenna A_1 will be $KIe^{j\left(\omega t-\frac{2\pi X}{\lambda}\right)}$ and that of antenna A_2 will be $KIe^{j\left(\omega t+\theta+\frac{2\pi(X+d)}{\lambda}\right)}$. Let the phase θ and the distance d be so chosen that at p_1 the



FIG. 113.—Directive transmitting with two antennæ.

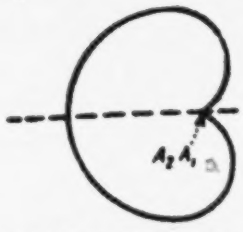


FIG. 114.—Typical direction-intensity characteristic for system of Fig. 113.

effects of the two antennæ neutralize. Then a difference in phase of π must exist between the two effects. Hence

$$\pm\pi+\left(\omega t+\frac{2\pi X}{\lambda}\right)=\left(\omega t+\theta+\frac{2\pi(X+d)}{\lambda}\right)$$

and

$$\pm\pi=\theta+\frac{2\pi d}{\lambda}\quad\text{or}\quad\theta=\pi\pm\frac{2\pi d}{\lambda}$$

Along the line A_1p_1 there will then be no transmission. Substitutions of this value of θ and of negative values of X, gives the effect in the opposite direction.

For any other direction the effect of each antenna may then be obtained in terms of the angle φ, shown in the figure, by writing $(X+d\cos\varphi)$ for $(X+d)$ in the above expressions.

[1] In this connection see the development of the wave equation of p. 112.

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If for each value of the angle φ there is plotted the resultant effect of the two antennæ a curve of the general form of Fig. 114 is obtained. The direction corresponding to the maximum is not necessarily A_1P_2 but depends upon the value of $\frac{d}{\lambda}$. This general method may be applied to determine the directive effect of any combination of antennæ

Bellini-Tosi Directive System.—In the system of Bellini and Tosi two inclined vertical antennæ A_1 and A_2 as in Fig. 115 are excited from a common tuned source S of such frequency that the currents in the two verticals are 180° out of phase. To provide for varying the direction of the maximum transmission, which is in the plane of the two antennæ, the inventors provide a second pair of antennæ the plane of which is at right angles to that of the first pair. The coupling coil M of one pair is then at right angles to that of the other pair. The coupling coil N of the source is arranged to rotate so that in one position it will have zero coupling with one pair of antennæ and a maximum with the other pair. In rotating this coil through 90° the excitation of the two directive systems is varied from a maximum for one system (through a 45° position of equal excitation) to a maximum for the other system. The direction of the electro-magnetic disturbance transmitted from the combined systems is thus variable at will.

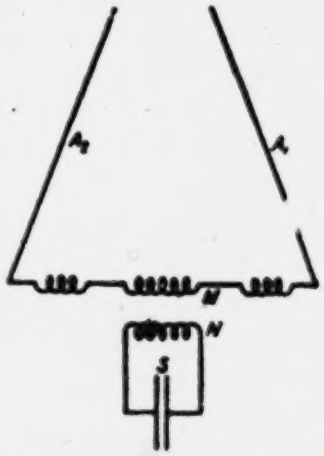


FIG. 115.—Bellini-Tosi direction system.

The apparatus is similarly applied to directive receiving in which case the rotating coil is connected to a receiving set. The position of the coil when the received signals are loudest will then indicate the line of direction of the distant source. In this form the system constitutes a "radio-goniometer."

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TRANSLATION COPY

JAPANESE PATENT NO. 70885

Classification 199
IX - High Frequency Communication - Miscellaneous

Applied for September 8, 1926
Published October 8, 1926
Patented December 27, 1926

Inventor: Hijiro Takagishi
Hiraiso Branch of Electric Experimental Station,
Hinde, Hiraiso-machi, Naka-gun, Ibaragi-ken.

DIRECTIONAL ANTENNA SYSTEM

This invention relates to a device for directional antennae and is characterized by providing for the passage of current waves from the transmitting station to the receiving station. The current waves are distributed over each conductor of the fundamental antennae. A plurality of groups of antennae are provided parallel to each other and within a plane covered by the transmitting station. Each succeeding loop of the oscillating current in a linear conductor is out of phase with respect to corresponding loops by a fraction of a whole number of radians. The linear conductor is inclined at some angle other than zero degree to the plane perpendicular to each fundamental conductor. Furthermore, the perpendicular distance between adjacent fundamental conductors is either equal to the product of the length equal to the above mentioned fraction of a whole number, the wavelength,

the cosine of a certain oblique angle, or very nearly so. AA/34

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The purpose of the invention is to furnish a directional antenna by which a desired result can be readily obtained at will when most of the energy of the electric waves is radiated in wireless telegraphy, and wireless telephony at a given altitude, above the ground or in receiving the electric wave travelling through the air at a given angle. Furthermore, this invention makes possible efficient communication by adjusting the radiation angle depending on the distance between the transmitting and receiving stations and depending also on the seasonal and atmospheric conditions. This applies particularly to short electric waves which are noted for their properties of reflection and refraction functions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of the antenna prepared for explaining the theory of the present invention.

Fig. 2 shows the dimensions of an antenna which was used in actual experiment and which was planned in accordance with this invention.

Figs. 3 and 4 are examples of applications of this invention.

Fig. 5-A shows another form of the arrangement of Fig. 4, while Fig. 5-B exemplifies its construction.

Figs. 6 and 7 are also examples of application

DETAILED EXPLANATION OF THE INVENTION

As a result of recent progress in studies of long distance communication by means of short waves it has been demonstrated that, if the waves are short, space waves perform a more important function than the surface waves. It has been theoretically proved that when, as has been known in the past, a vertical antenna of a comparatively short characteristic wavelength is employed for transmission, the energy of the electric waves is greatest in a horizontal direction. On the other hand, when such antenna is replaced by an antenna which has a large natural wavelength, the direction of radiation of maximum energy of the electric wave is to some extent inclined to the horizontal.

According to S. Ballantine's calculations the relation between the angle made by the direction in which maximum radiation is emitted and the horizontal plane, and the order of the harmonic in which a vertical antenna is emitted is given by the following table arranged in accordance with the order of the harmonic:

No. of Harmonic	Angle against Horizontal Plane	Comparative values of Electrical Energy
3	49°	1.48
4	60°	1.05
25	78°	4.85

Heretofore, in order to handle long distance communication with short waves in accordance with this theory,

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either vertical antennas of other types of antennas located at proper heights and working at the proper harmonic have been used.

The correctness of this theory has been verified by actual experiment in communication.

To start with, there are two kinds of directional characteristics an antenna can have; i.e., one has to do with directivity in the horizontal plane and the other with directivity in the vertical plane, i.e. in elevation. Directional antennas of known types belong mainly to the former kind whereas the one constructed in accordance with this invention, which will be presently explained, belong to the latter kind.

In accordance with this invention the bulk of the radiated energy is directed at some angle to the horizontal plane. This is controlled by proper positioning and phasing of two vertical antennas instead of primarily choosing the order of the harmonic, as has been done heretofore.

This method makes it simple to adjust the angle at which maximum electric energy is radiated.

The following is a detailed description of the antenna system.

In Fig. 1 straight lines a n_1 c and c'n_2' c' respectively, indicate vertical antennas A and B. These antennas are parallel to each other and are spaced distance D apart.

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The curved lines a b c d and A' B' C' D' indicate the distribution of oscillating current in the antennae. n_1 and n_1' are positions of current loops. The phases of n_1 and n_1' are reversed (opposite). The straight line n_1 n_1' makes an angle with the plane perpendicular to the antennae A and B and this angle is θ. It is clear that in this case the combined electric field produced by portion a c of linear conductor A and portion c' d' of linear conductor B is greatest within the plane containing the two antennae and least within the plane perpendicular to the antennae.

If the plane of the antennae is made to coincide with the vertical plane of the earth's globe, then the electric field will vary with altitude above the horizon; that is, the field in the direction of straight line n_1 n_1' which connects two corresponding points on portion a c of antenna A and the other on portion c' d' on antenna B is greatest as the distance between the two points approaches a half wavelength or odd multiple thereof. Certainly, the electric field located in the direction of the straight line which connects the two points becomes weaker as the distance between them approaches one wavelength or a multiple thereof.

Since electric current at loop n_2' along antenna B is in the same phase as the current at loop n_2 along A, it follows that the distribution of electric field in the vertical

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plane and in direction $R_2 R_2'$ behaves in a manner exactly opposite to that described above; that is, when the distance $R_2 R_2'$ approaches a half wavelength or odd multiple thereof, the field is least, and it is greatest when that distance approaches an integral number of wave lengths.

In the light of these facts it appears that when distance $R_2 R_2'$ reaches either half wavelength or an odd multiple thereof, the electric field in the direction of the straight line $R_2 R_2'$ is greatest and, therefore, the energy of the electric wave is maximum at this direction while lying within the vertical plane.

The relation between angle θ, which is important in the construction of directional entennae in accordance with this theory, and the distance D between the antennae may be stated as follows:

$$D = \frac{\lambda}{2} N + \frac{\lambda}{4} \cos \theta \qquad (1)$$

In the above formula:

λ = the wavelength used. When the phase difference between the antennae A and B is not π radians, as in the ordinary case but is $\theta\pi\left(N + \frac{1}{2}\right)$ radians, the following equation must be used:

$$D = \lambda\left(N + \frac{1}{2}\right) \cos \theta \qquad (2)$$

provided N and n represent positive integral numbers. In formula (1) when $\theta = 0$, a special case, the distance between

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the antennae becomes equal to an odd number of half wavelengths. This kind of directional antennae have been widely known.

What this inventor desires to secure by this patent are points other than those already known. Therefore, the main point of this invention relates to the method of effecting high angle of radiation of electric waves by means of a special arrangement of antennae. When θ is more or close to it the application of this invention does not produce much effect. On the other hand, with the exception of cases where the angle is small, this invention makes possible the securing of effective results in high angle radiation and I desire to secure a patent for this.

In order to test the results obtained by means of this invention at Hiraiso, Ibaragi Prefecture a system of very simple antennae for broadcasting has been erected in accordance with the theory of this invention, and the strength of reception was tested at Ushishi, Hokkaido. That is, at Hiraiso two linear conductors A and B were erected perpendicularly to ground and a distance D apart and the vertical angle of radiation adjusted by changing the heights h_a and h_b of the two radiators and the spacing between radiators. There were four adjustments as shown in the table below. Care was taken to keep the antennae and ..shishi all in practically the same plane. The wavelength used was 40 meters. The test was made in the forenoon during ..nter.

AA/HO

H_1 (meters)	H_2 (meters)	D (m)	Altitude of Maximum Radiation	Strength of Received signal (receiving set resistance).
26	26	30	60°	8 ohms
26	16	19.5	53°	6 "
26	11.84	14.14	45°	2 "
26	8.9	10	30°	--

The final reason of the test may be seen in the last column of the above table. According to the results of this experiment as the altitude of radiation increases the strength of the received signal also increases.

Although among the tests the one with the radiation altitude of 45° shows the best result under the conditions prevailing when the test was performed, this result will vary depending on the atmospheric and other conditions. In order to explain the theory clearly in the above description a case of directional antennae which are fundamentally merely two vertical linear conductors has been cited, but the theory of this invention can be applied in other instances where a combination of these linear radiators is effected. Two or two examples of this kind may be given as follows:

In Fig. 8 A_1 and B_1, which are a pair of antennae, are arranged and function like A and B of Fig. 1, and A_2B_2, A_3B_3 are also paired antennae. The distances between A_1, A_2 and A_3 are equal to either half wavelengths or whole multiple

thereof or very close to these figures. Accordingly, phases of electric currents distributed on corresponding parts of each antenna are made either equal or else opposite. Thus, the radiation within the plane which includes the antennas A_1, A_2, A_3 and others can be made almost zero.

In the case of A_1, B_2 and B_3, etc., the same condition is supposed to prevail whereby the arrangement in the figure is realized.

Furthermore, a group of paired antennas when given proper distribution of current will manifest directivity not only in the horizontal plane but also in the vertical plane.

In Fig. 4 the number of antennas shown in Fig. 1 is increased within the same plane. All of the current loops n_1 n_1' n_1'' n_1''' on the various antennas A, B, C, D are located on the same straight line and θ is taken as the angle with the horizontal plane. If the distances between the neighbouring loops n_1 n_1', n_1' n_1'', etc., are made equal to half a wavelength and the phases made opposite in order, the desired effects of electric currents in every antenna will superpose in the directions of the straight line n_1 n_1' n_1'' n_1''', thereby increasing the strength of the electric wave in the same direction. The antennas C and D are not necessarily made gradually higher than the antenna A B. This is shown in Figs. 5A and 5B. In Fig. 5A the antennas A B and C D are the same antennas as the ones shown in Fig. 1. However,

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In this instance it is necessary to arrange both groups in proper relations so that electric fields of the antennae A B of the first group and the antennae C D of the second group reinforce each other in the direction of C. This case is the simplest example where A and B are of equal height while C and D are of the same height and where the relationship of position of each antenna is considered important as shown in Fig. 8B. In Fig. 6 only the same phase of current distribution on each antenna is made effective, for instance, by partly bending the part of the antenna A on which current of a certain phase is distributed and thus disabling it as a radiator, and leaving that part on which current is distributed in the same phase, and arranging in the same manner the current distribution on the other antenna B either in the same or in the reverse phase depending on the distance between the antennae A and B. If the directional method of this invention is applied to a pair of antennae thus arranged, the effect will be particularly remarkable.

In Fig. 7 a large number of antennae B_1 B_2 B_3 ... B_n, etc., are arranged in a circle around the antenna A_0 the distance being $\frac{\lambda}{8}$ cos θ as the radius. In accordance with the theory which has been explained above, the antennae A B are made to radiate at altitude of θ. The phases of the current on the antennae A and B are reversed. Under such circumstances it is desirable that they radiate with sufficient

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effect at the altitude of 0 in every direction around the column A.

In the above explanation, for the sake of convenience a special case where the phase difference of current on the columns A B is π radians and the distance between them is $D = \frac{\lambda}{8}$ cos θ. However, the theory of this invention applies also, in general, and when it is applied in accordance with formula (1), the same result will be obtained.

Considering Fig. 1, since the distance between a_1 and a_1' is $\lambda/8 + \frac{\lambda}{8}$, if the phase of current of the antenna A is advanced by $\pi/2 + \frac{\lambda}{8}$, i.e., $\frac{5\pi}{8}$ against that of the antenna B, they radiate the main energy in the direction AB. This can be readily understood in the light of the foregoing explanation.

Advancement and retardation of the phase may be easily secured, for example, by having one of the columns A B as a reflecting help. In this case the best effect of reflecting function is obtainable at $D = \frac{\lambda}{8}$ or its odd multiple or the one nearest to even figure.

[illegible]

A directional antenna system which has been described in detail in the specification and shown in the drawings, characterized by the energy of electric waves from the transmitting station to the receiving station distribution on each three conductor of the fundamental antennas, erected parallel to each other, within a plane which the transmitting station

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inclined, and in phase, each successingly having a difference of a function of integral number of π radians, and corresponding loops of each oscillating current are located along a straight line, which is inclined to a plane perpendicular to the main antenna, and at a slight angle. At the same time the vertical distance between the neighboring fundamental antennae is equal to the product of the length, equal to the same function of the integral number previously mentioned, and the cosine of the oblique angle, or very close to it.

Additional claims.

1. A device of directional antennae which is included in the scope of claims of this patent and which is characterized by having the two fundamental antennae, one of which is employed to function as the reflecting body and having the perpendicular distance between the antennae equal approximately to an integral multiple of one-fourth of the wavelength.

2. A system of directional antennae which is described in the scope of claims of this patent and which is characterized by having the directional antennae, composed of several multiple fundamental antennae as the element in a plane or in a plane which is perpendicular to said plane, these elements being arranged in the plane so that the action of every one is added to that of the other.

AA/HS

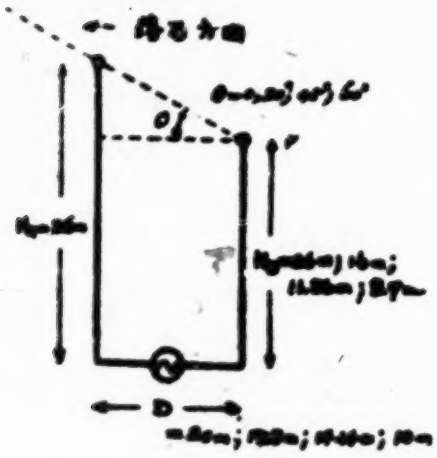
5. A directional antenna system which is described in the scope of claims of this patent and which is characterized by having directional antennas, composed of several multiple fundamental antennas as the element around one of which constituting a common axis the other antennas are arranged. AN/46

特許第七〇五八三號

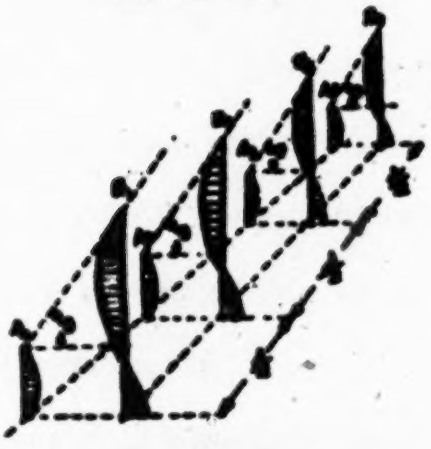
圖一第



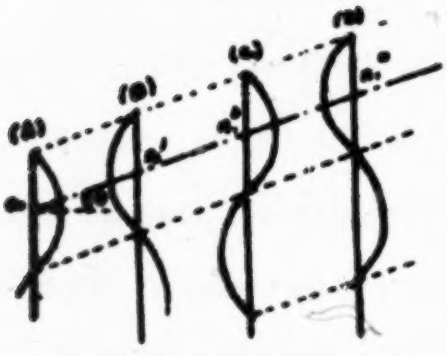
圖二第



圖三第



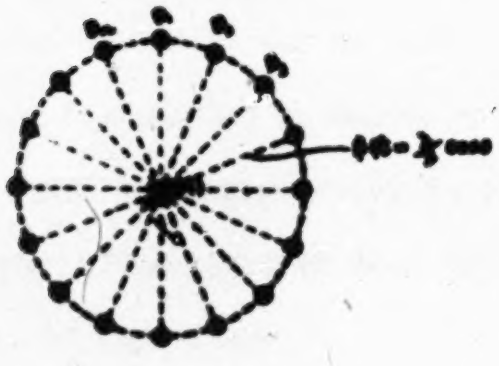
圖四第



圖六第



圖七第

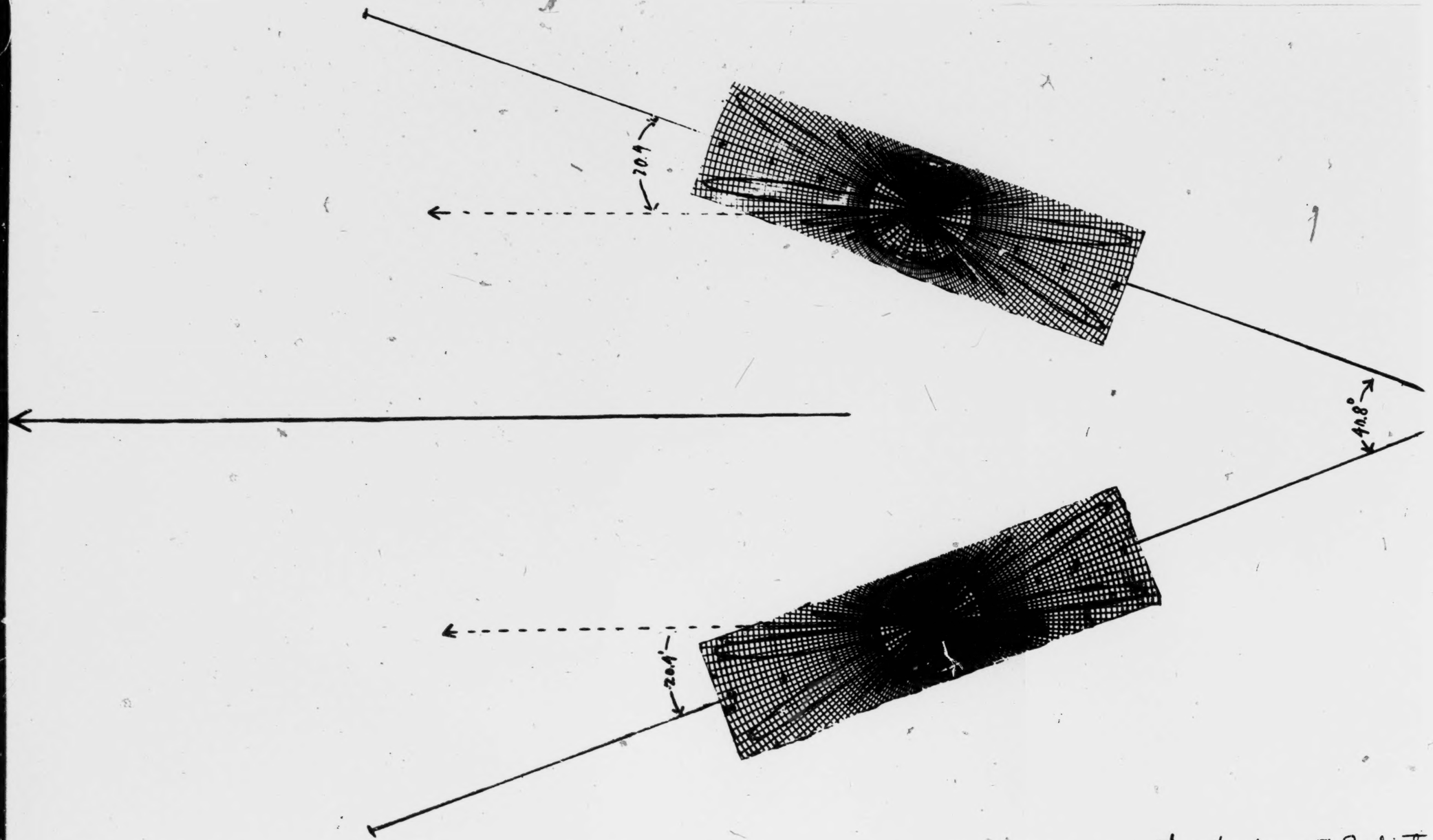


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第五圖

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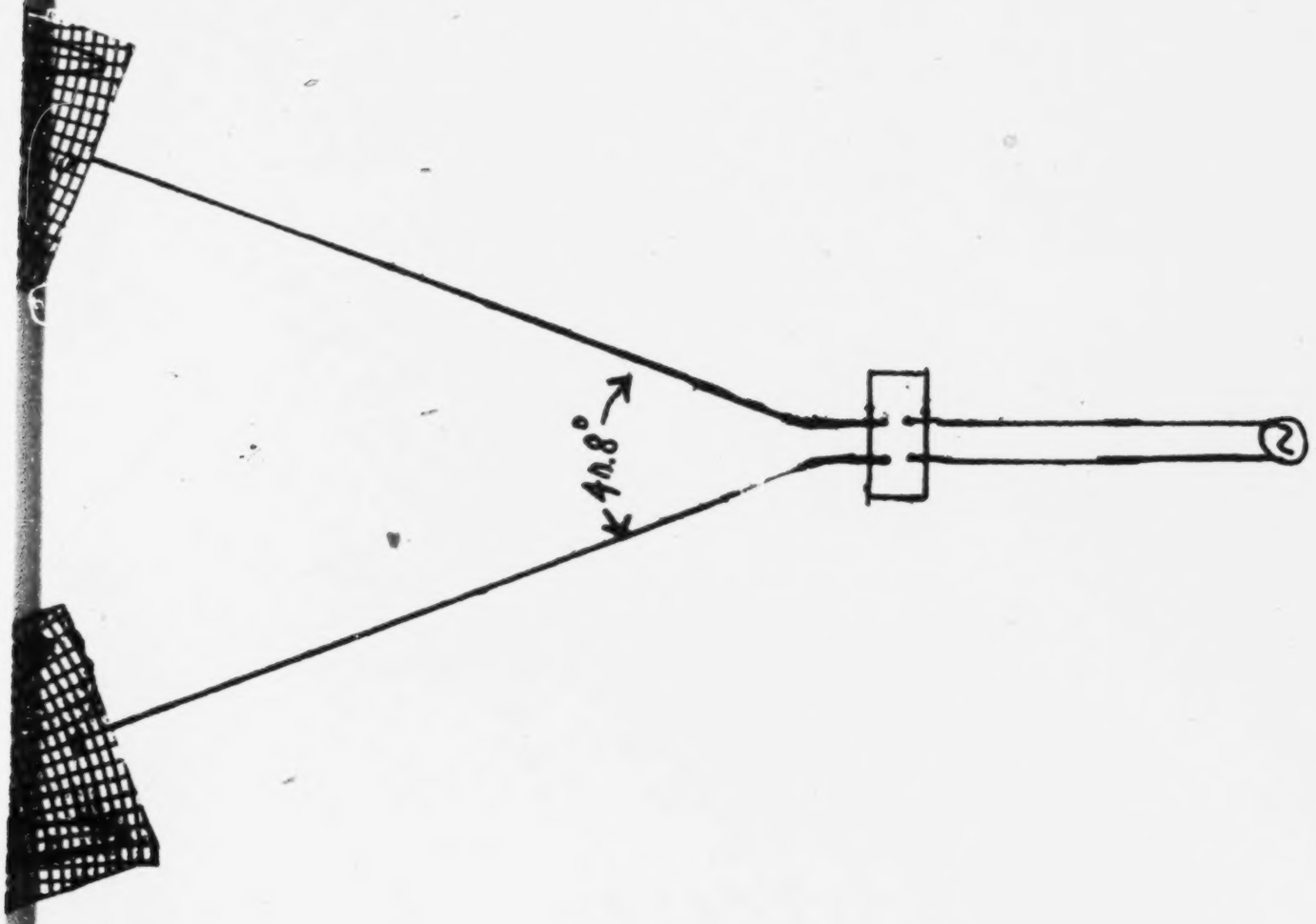


This Vee does not Radiate

Wires are 16λ

896 - 1103

DEFENDANT'S EXHIBIT BB

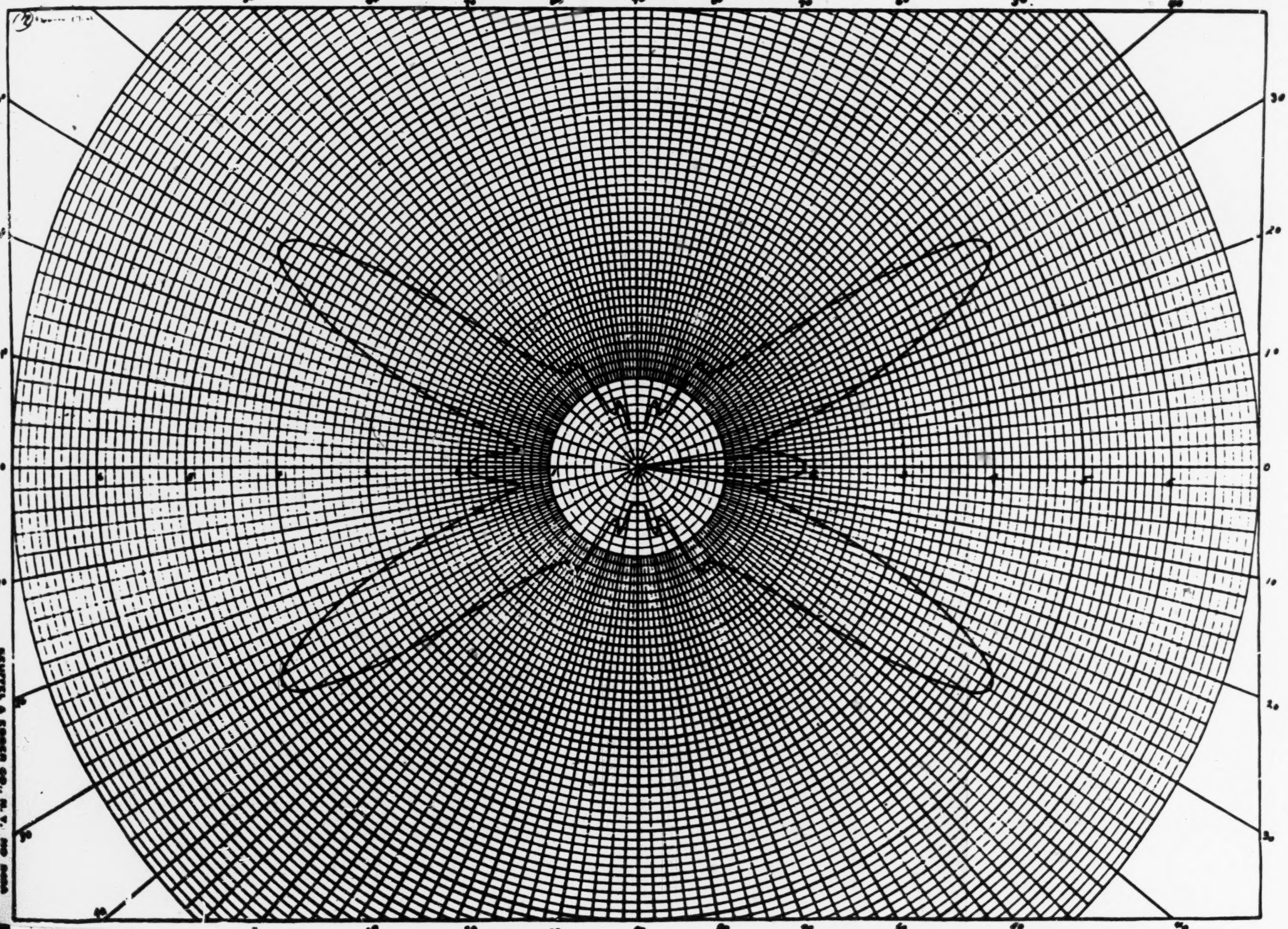


This Vee does not Radiate along the bisector.

Wires are 1 6 λ long

Radiation Pattern of V when $\frac{s}{\lambda} = 4$

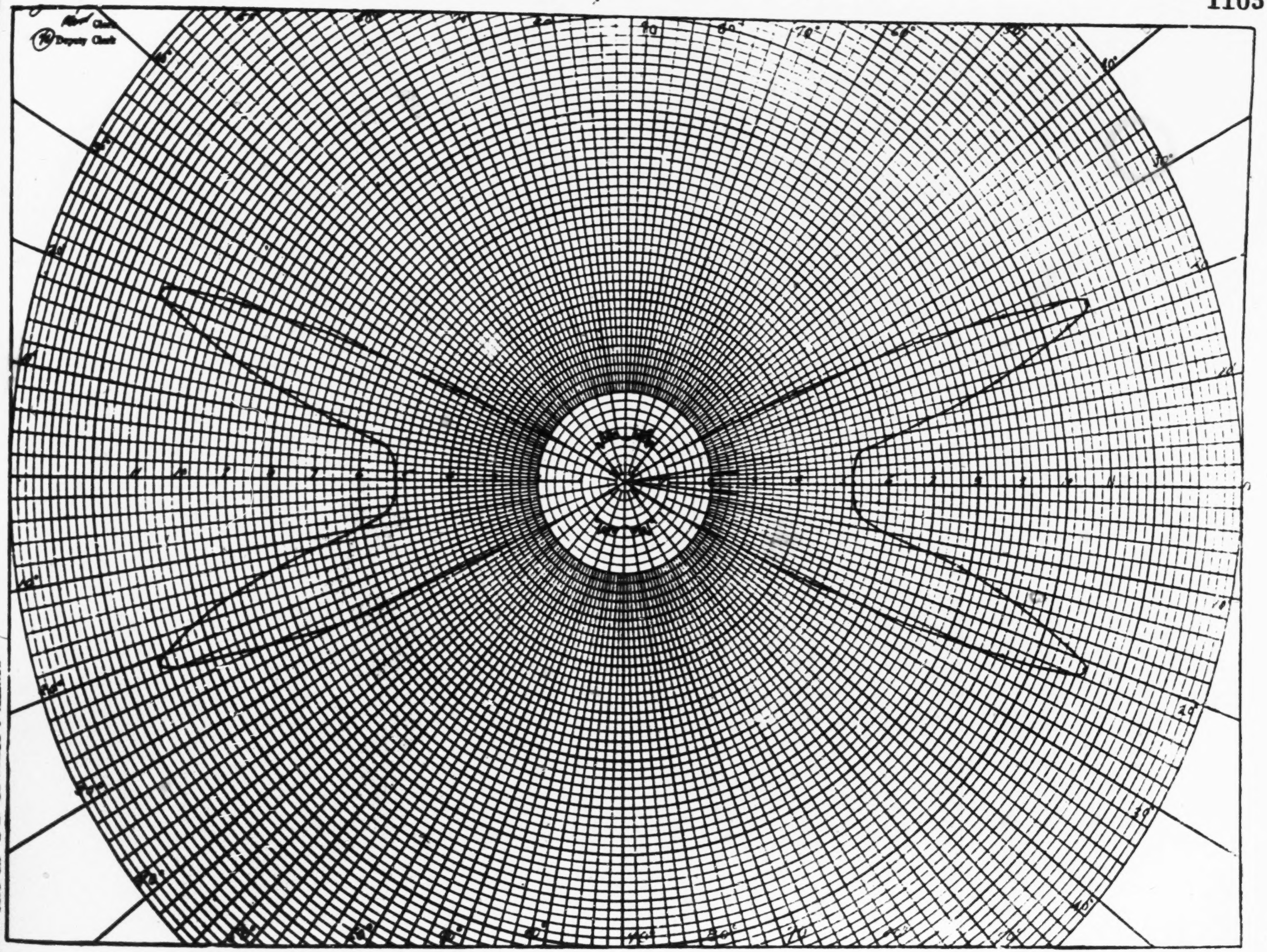
Angle of V = $2 \tan^{-1} \frac{1}{10} = 11.42°$



RADIATION PATTERN V ANTENNA

$\frac{L}{\lambda} = 8$ ANGLE OF V = $2 \tan^{-1} \frac{1}{10} = 11.4°$

DEFENDANT'S EXHIBIT DD
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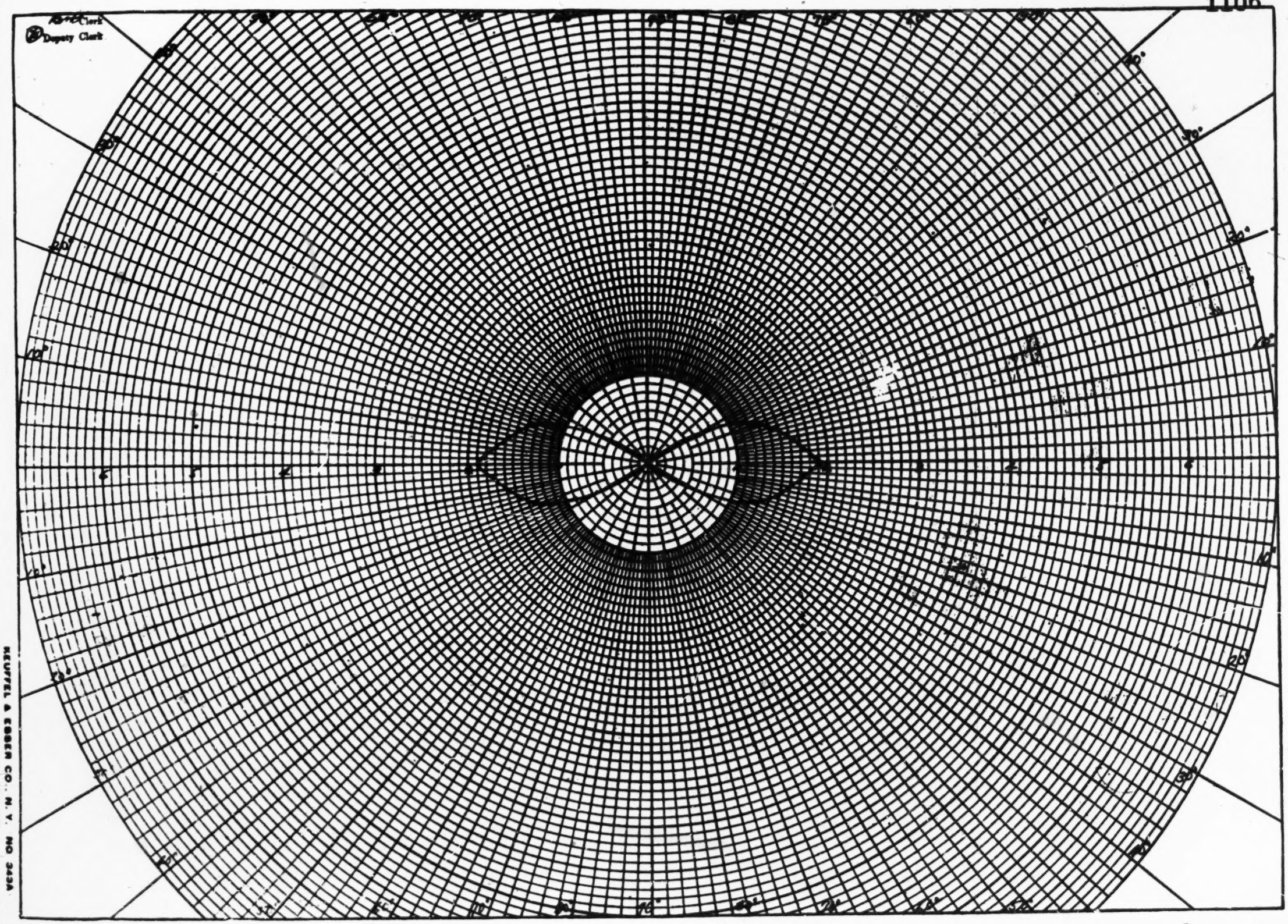


RADIATION PATTERN OF V IN BISECTOR PLANE
ANGLE OF V = $2\tan^{-1}\frac{1}{10} = 11.4°$
$L/\lambda = 4$

DEFENDANT'S EXHIBIT FF

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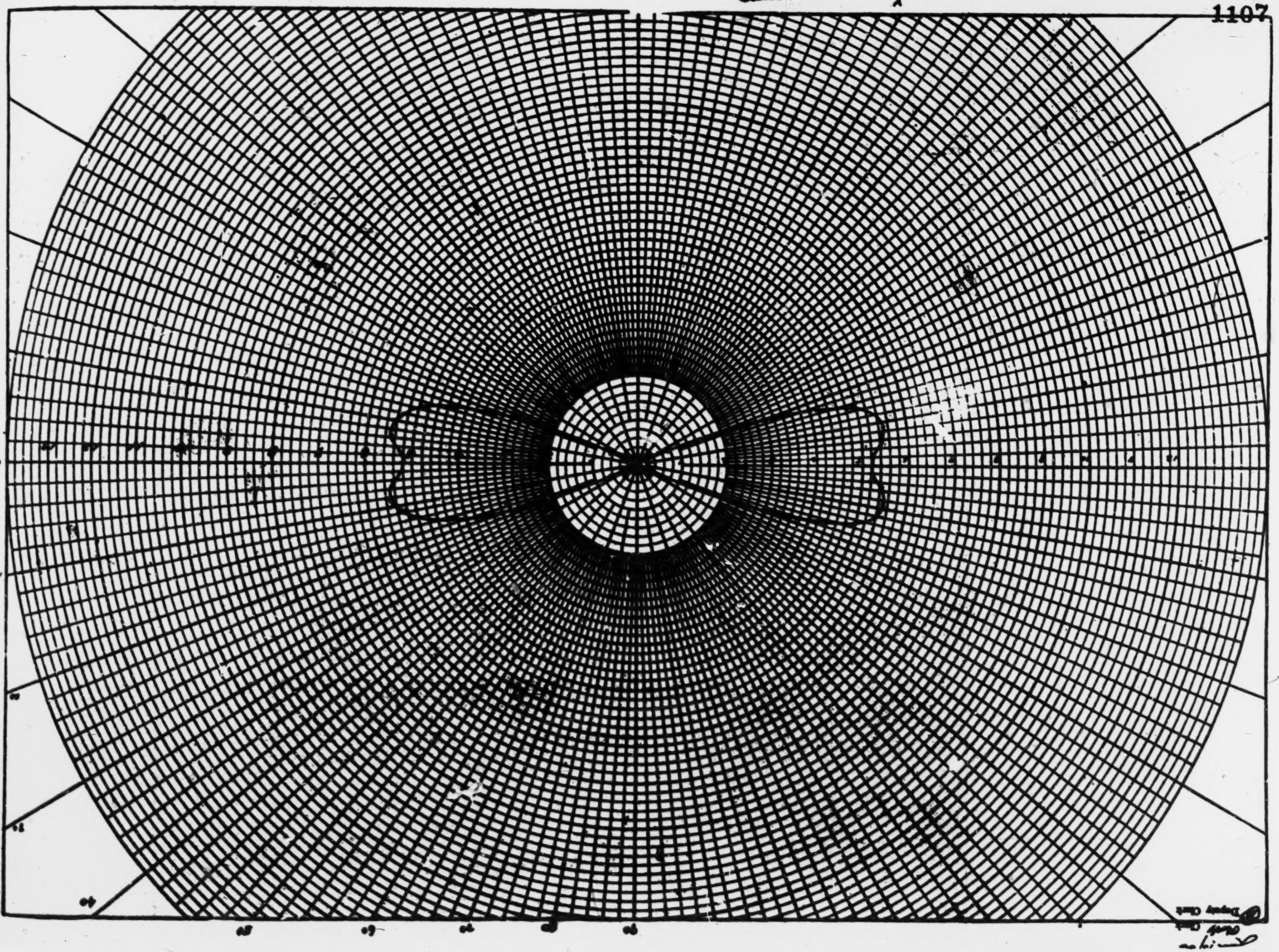


POWER

$\alpha = 6.71°$
Bisector Plane $\frac{l}{\lambda} = 8$

DEFENDANT'S EXHIBIT GG 900

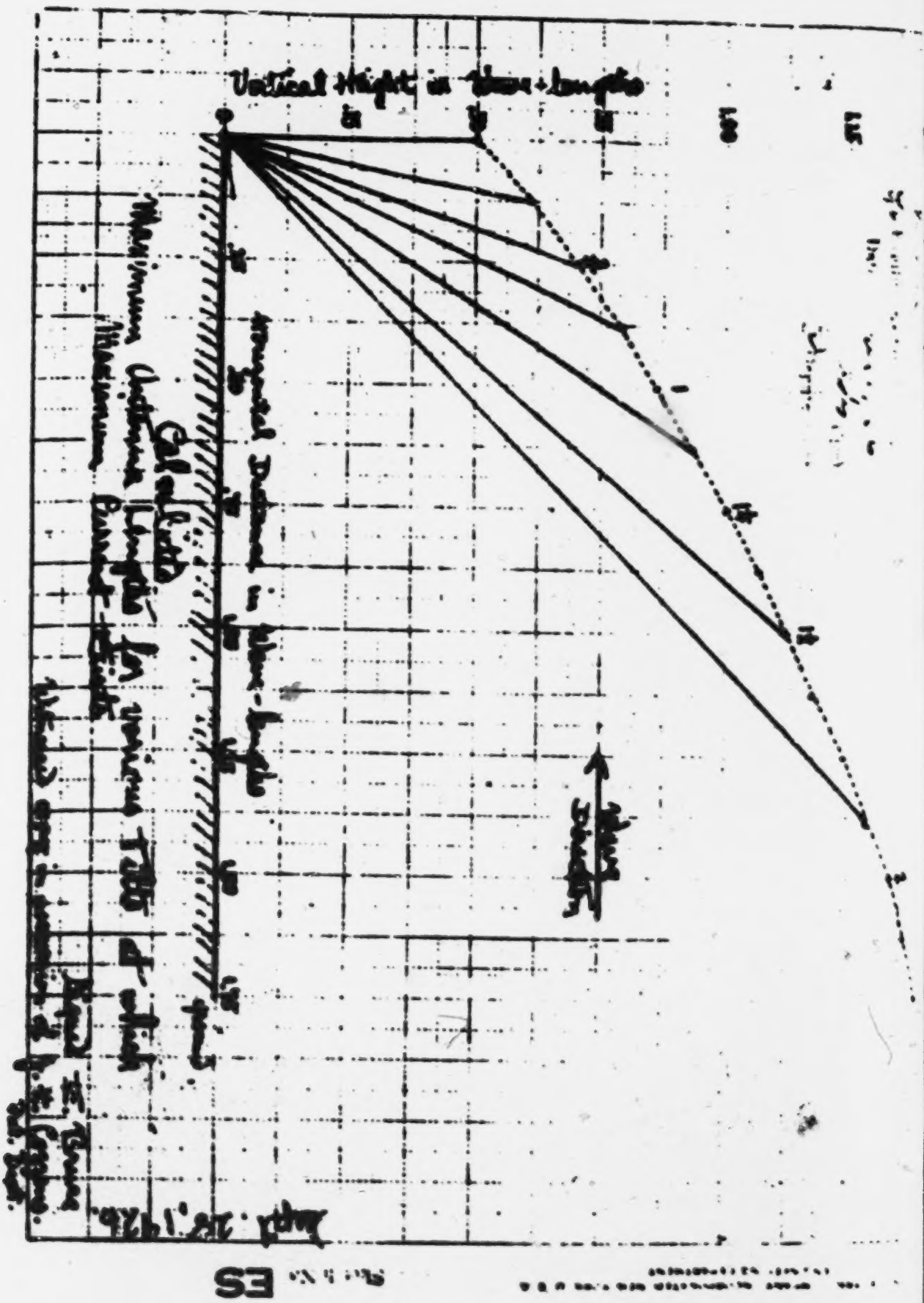
1107



KEUFFEL & ESSER CO., N. Y. NO 8466
POLAR COORDINATE

DEFENDANT'S EXHIBIT HH

DEFENDANT'S EXHIBIT J J



DEFENDANT'S EXHIBIT KK

sity of radiation is proportional to

$$\frac{\cos^2\left(\frac{\pi m}{2}\cdot\cos\varphi\right)}{\sin^2\varphi}$$ for the odd numbered and

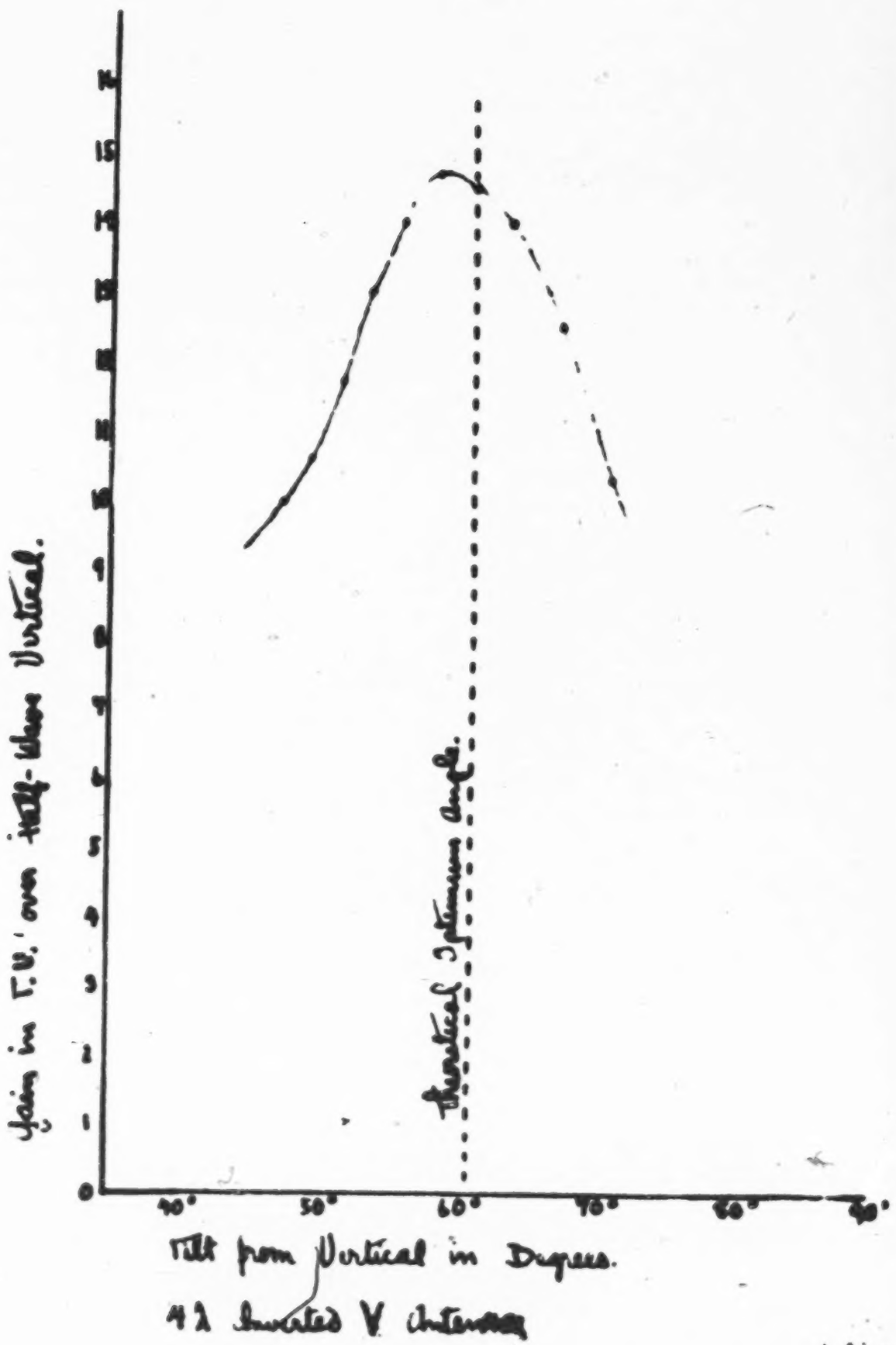
$$\frac{\sin^2\left(\frac{\pi m}{2}\cos\varphi\right)}{\sin^2\varphi}$$ for the even numbered periods

d also,-

$$\frac{\cos\left(\frac{\pi m}{2}\cos\theta_0\right)}{\sin\theta_0}$$ for odd number of half wavelengths.

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DEFENDANT'S EXHIBIT LL



July 25, 19

DEFENDANT'S EXHIBIT MM

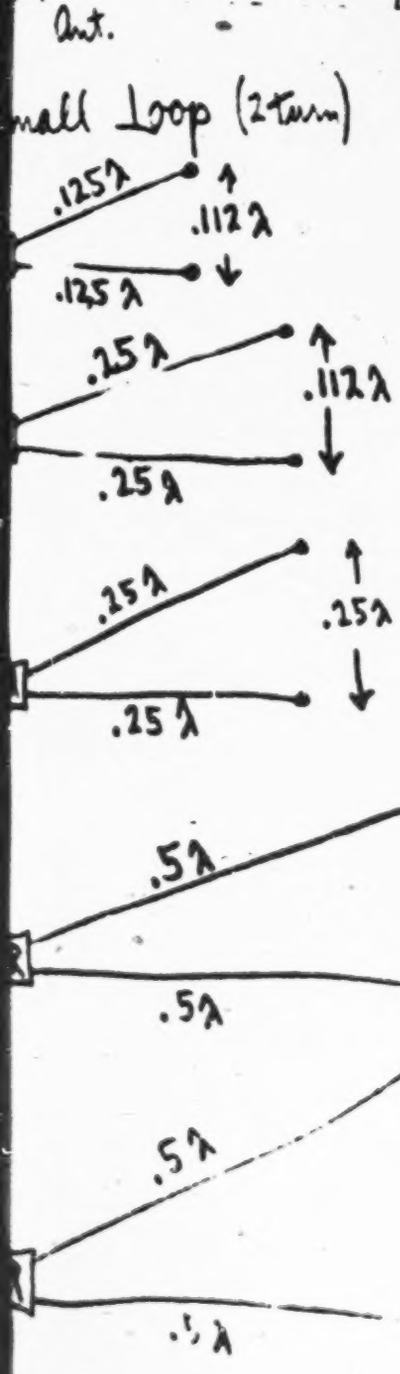
May 13, 1926.

Litton took his set back to Deal.

following antenna comparisons with a loop
e made:

Entire test. Distant oscillator, output constant

freq. = 12.2×10^6 $\lambda = 24.6$



Ant.	Setting for constant output.	Coil resonant antenna Turns of inductance	Capacity dial
Small Loop (2 turn)	10		
.125λ .112λ .125λ	75	2	5
.25λ .112λ .25λ	68	2	67
.25λ .25λ .25λ	95	1	73
Several Turns	75	2	60
	75	3	52
	65	4	51
.5λ .25λ .5λ	70	2	12
	58	1	41
	Evidences of approaching resonance beyond extreme limits when Turns = 3 and 4.		
.5λ .375λ .5λ	75	1	40
	62	4	8
	Pronounced [illegible] beyond limits evident when Turns = 2 and 3.		

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May 14, 1926.

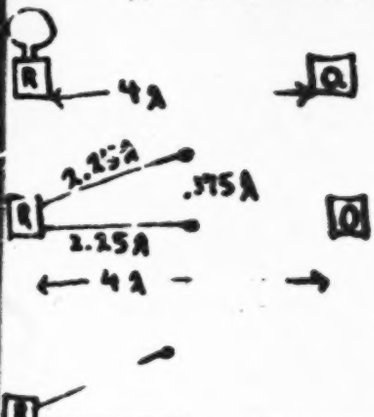
Yesterdays antenna results seem roughly reasonable according to Letcher wire theory together with reappearing resonances for loads of various hyperbolic angles.

dt is definitely decided that d will sail for England with Southworth and Hubbard about May 27. Telephoned to see what is necessary to get passports. Wilson recommends that d do this tomorrow

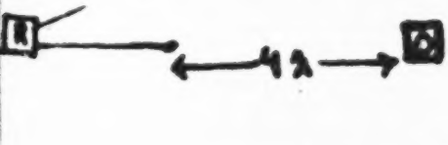
May 14, 1926.

Measurement of Antenna Directional Characteristic and its comparison with a Loop Maximum as given by attenuation ratios for same output.

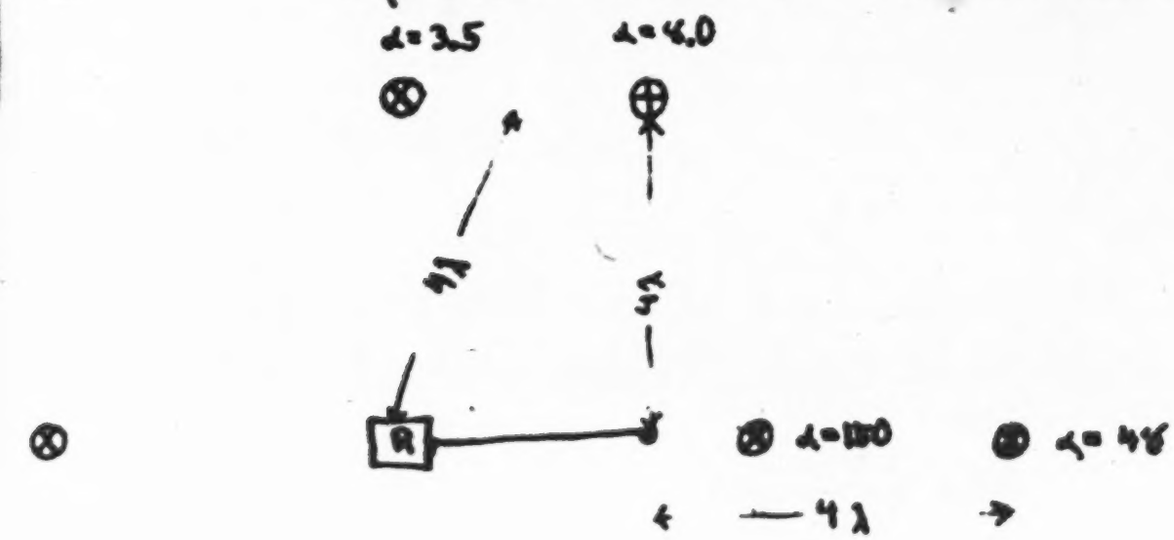
λ 24.6 meters



	Atten. for output	Unit-resonant antenna turns. Turns of L.	Cap. Division
	10	—	—
	150	1	55
	150	4	20
	48	1	55
	48	4	20



Top View Directional Characteristic



May 15, 1926

went to N.L. to make application for pass ports. nm.

Tilted Wire Measurements at Deal on 14 meters July 19-21, 1927.

Small transmitter at a distance. Measuring set [illegible]

Antenna Length	Output Defl.	T.U.	Optimum Coupling	Horizontal Ant. at Tilt	ϕ	TU change
$\frac{\lambda}{2}$	100	8.8	$\frac{2.5}{6}$	0°		—
λ	100	11.9	$\frac{1.5}{6}$	-19°		2.1
2λ	100	17.5	$\frac{1.5}{6}$	-57°		8.7
4λ	100	20.5	$\frac{1.5}{6}$	-150°		11.7
4λ	100	18	$\frac{1.5}{6}$	$+\left(\frac{\text{[illegible]}}{150°}\right)$		9.2



Note: Experiment showed that it is apparently important to avoid sagging in the tilted wires.

August 2, 1927.

Using one of the long tilted wires as an element, it is desirable to find methods of using them in arrays. Economy demands, first, studying the combinations which require only one supporting pole. The simplest scheme is shown below.



Example:
Each element = λ

Induced Voltage →
Effective Voltage → →
Current at R
Direct ← ←
Reflected ← ←

Note: More vector points along the wire are necessary to show this last case.
I.B. 8-8-29

It is seen that the tilts of each element are maintained the same as if they were alone. It is also seen that with the above arrangement, no radiation can take place in the YZ plane.

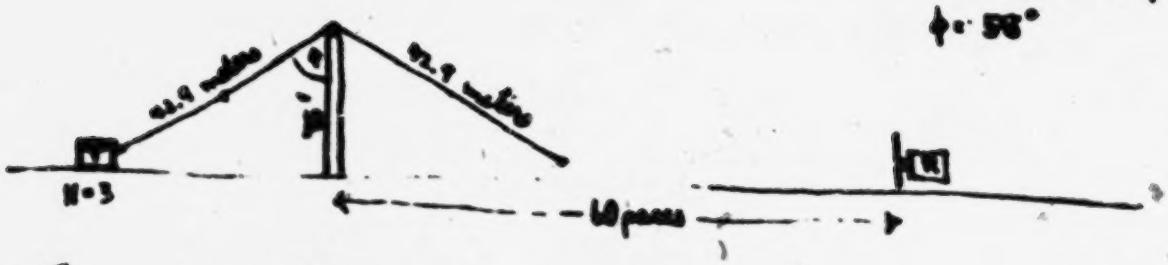
Signed. E. Bruce 8-2-27

8-2-1927
F J Jans

MW.

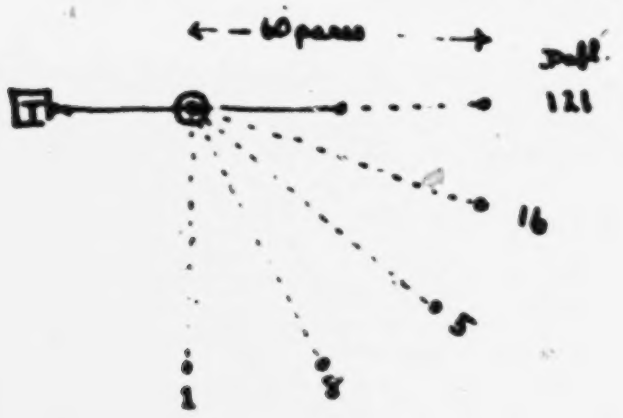
9, 1927.

92.9 − 60 = 141 ft.
$\phi = 58°$



Transm. Cond.	Unit. Current	Recv Cond.	λ	Diff.		Wave length in λ.
5	.100	8	12.1	52-33 = 19		3.28
10	.090	10.5	13.3	52-33 = 19		3.23
15.	.096	13.5	13.6	60-33 = 27		3.16
20	.060	20	14.5	78-33 = 45		2.96
25	.100	26	15.6	118-33 = 85		2.75
30	.090	28.5	16.0	102-33 = 69		2.68
35	.100	35	17.1	130-33 = 97		2.50
40	.090	37.5	17.5	130-33 = 97		2.45
45	102	44	18.8	164-33 = 131	Optimum	2.28
50	.090	47	19.4	128-33 = 95		2.21

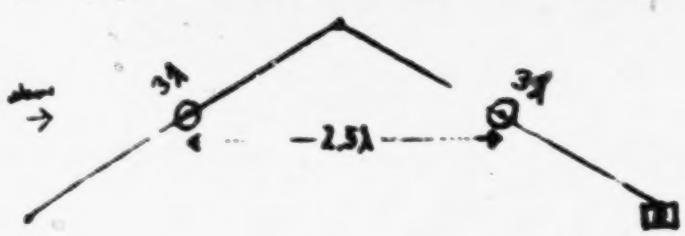
Directional Characteristic for Optimum.



Note: Horizontal ϕ for optimum $L = 2.28$ is $\phi = 51°$

Aug: 10, 1926.

Methods of using tilted wires in combination
In order to illustrate the principles involved,
a 3λ tilted wire is used as an element.

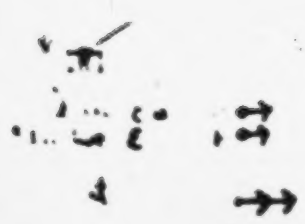


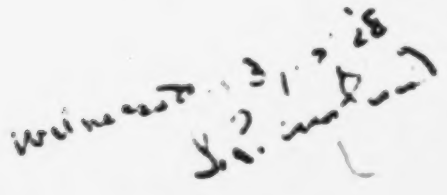




Note: Wire distance between
a and c must be a
multiple of λ. for in phase
addition

Signed E. Bruce Aug 10, 1926.





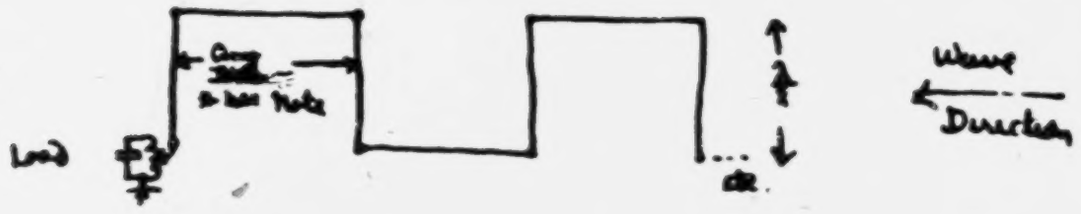
912
1121

March 5, 1930. (2)

Continued

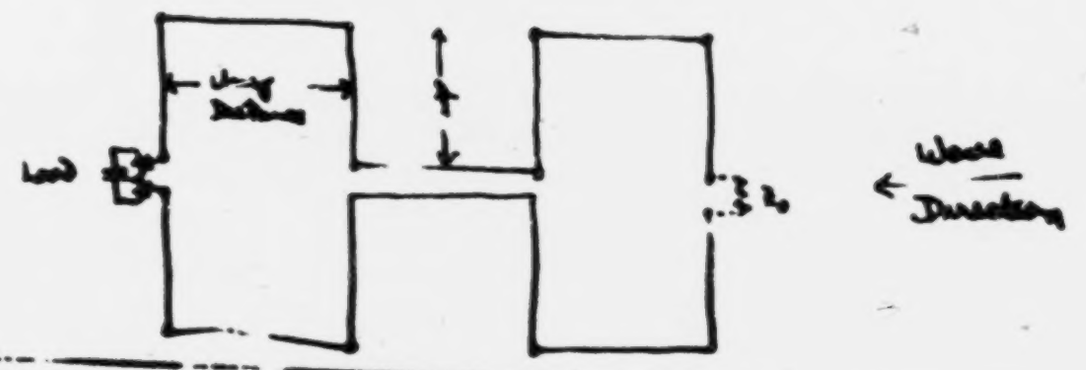
Antenna Schemes for Horizontally Polarized Waves.

(5) Plane of Antenna Horizontal.

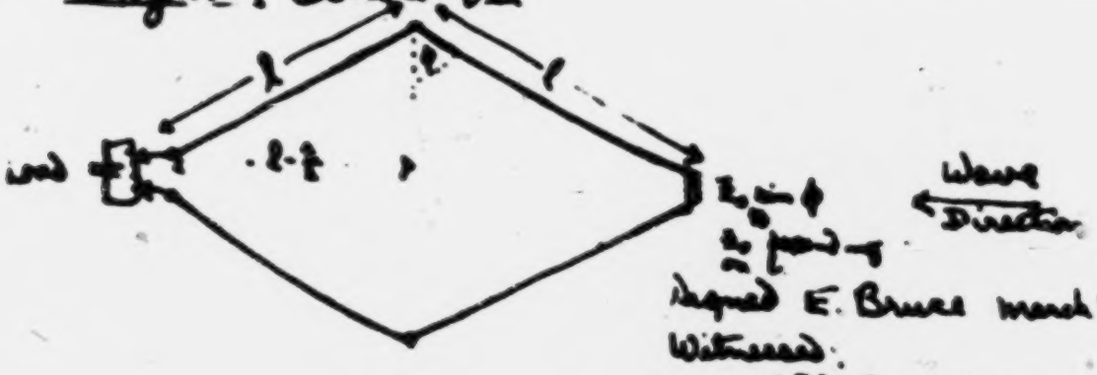


* Note: this distance should be preferably such that the standing waves reduce radiation. Example: One wave-length. It is also probable that this antenna can be terminated with its surge impedance to become uni-directional.

(6) #5 in double form.



(7) Horizontal Double-Vee



Signed E. Bruce March 5, 1930
Witnessed.

1122-1123

2/25/31

Bruce

Spoke to Frus this morning about the tapped antenna that you phoned about last week

Frus was of the opinion that you were interested in dates.

According to my records my last trip to Cliffwood was at 3rd 9th 1926. He was then that you mentioned the tapped (leaning) antenna

J. V. Byers

MM/9

DEFENDANT'S EXHIBIT NN

Proceedings of the Institute of Radio Engineers
Volume 19, Number 8 *August, 1931*

DEVELOPMENTS IN SHORT-WAVE DIRECTIVE ANTENNAS*

By
E. Bruce
(Bell Telephone Laboratories, Inc., Holmdel, N. J.)

Summary—Part 1 of this paper discusses the relative importance of the factors which limit the intelligibility of short-wave radio telephone communication. The more important of these factors are inherent set noise, external noise (static, etc.), and signal fading. The possibility of counteracting these limitations through antenna directivity is indicated.

Part 2 describes an antenna system which maintains a desirable degree of directivity throughout a broad continuous range of frequencies. The cost of this antenna is more favorable than that of many types of fixed frequency antennas of equal effectiveness.

Introduction

BEFORE discussing specific antenna systems, it appears desirable to review the general problems of short-wave communication and to observe wherein antenna design can assist in overcoming existing circuit limitations. Accordingly, this paper is divided into two parts; the first will outline the requirements in the problem, and the second will be a description of an antenna system which has proved effective, despite its low cost of construction.

The writer's experience with antenna systems has been largely confined to the standpoint of reception, therefore, the following discussion will be largely on this basis. It will be apparent to the reader, however, that many of the features are likewise applicable to transmitting antenna installations.

PART 1. THE SHORT-WAVE PROBLEM

Radiotelephone Circuit Limitations

An analysis of the factors limiting the excellence of the output quality of a receiver governs the design of the entire radio circuit and associated equipment. Assuming well-designed apparatus throughout, we still encounter difficulties, especially at times of low signal strength, the more important of which are enumerated as follows:

(a) Inherent receiver noise.
(b) External noise (static, man-made noises, etc.)
(c) Signal fading.

* Decimal classification: R126. Original manuscript received by the Institute, April 28, 1931. Presented before Sixth Annual Convention, June 6, 1931, Chicago, Illinois.

The design of the receiving antenna system has an important bearing upon all three of these factors, brief explanations of which are given below.

(a) Receivers of very high gain characteristics are troubled with an inherent noise adequately described as a "hissing" sound. This may be due to several[1] causes such as shot-effect, etc. Much of this noise can be minimised through proper design, the methods of which are beyond the scope of this paper. Finally, however, an apparently irreducible minimum of noise is encountered, commonly referred to as[2] "Johnson" or circuit noise. This noise, under conditions of matched impedances, is so related to the circuit signal efficiency that the ratio of noise to signal cannot be appreciably altered except through somewhat impractical expedients such as lowering the absolute temperature of the circuit. All this tends to show that the designer of receivers must eventually rely upon his being able to increase the signal outputs from antennas to override the residual receiver noise difficulties on low field strength signals.

(b) Unpublished work, by a member of our laboratories,[3] has indicated that on many occasions short-wave static is highly directional. Interfering signals and electrical noises of human making are, of course, directional. It is quite evident that where the desired signal direction differs from that of the interference, receiving antenna directional discrimination is of immense importance.

(c) At times, remarkable reductions in short-wave fading have been achieved through extremely sharp directional characteristics of the receiving antenna. On the basis that certain types of fading are due to phase interference between multiple path signals of varying path length, it is reasonable to believe that where an angular difference exists between these paths, fading can be reduced by directivity which accepts only one of the paths. This, of course, assumes that the accepted path is stable in its direction. When this is not true, the reduction of fading through directivity becomes difficult.

The Relative Importance of the Various Circuit Limitations

The most serious hindrance to reliable, long-distance, short-wave communication is the great loss in signal fields which accompanies magnetic storms. Maintaining service under such conditions, develops into a battle against set noise and static. It is during these periods

[1] F. B. Llewellyn, "A study of noise in vacuum tubes and attached circuits," Proc. I.R.E., February, 1930.

[2] J. B. Johnson, "Thermal agitation of electricity in conductors," *Phys. Rev.*, 32, 97, 1928.

[3] K. G. Jansky, Bell Telephone Laboratories.

that effective receiving antennas are the most appreciated. The research worker on receiving antenna systems always welcomes such periods for his experimental work, since he knows well that under conditions of strong signals, a simple antenna appears to perform as well as one considerably more elaborate and expensive.

Fig. 1 will assist in comparing the relative importance of set noise and static interference. The figure is not intended to be strictly accurate as to numerical values but will convey the idea of the principles involved. There is plotted as a function of wavelength, for an arbitrary location and season, the average static voltage level delivered to the first tube of a receiver by a half-wave, vertical antenna through its

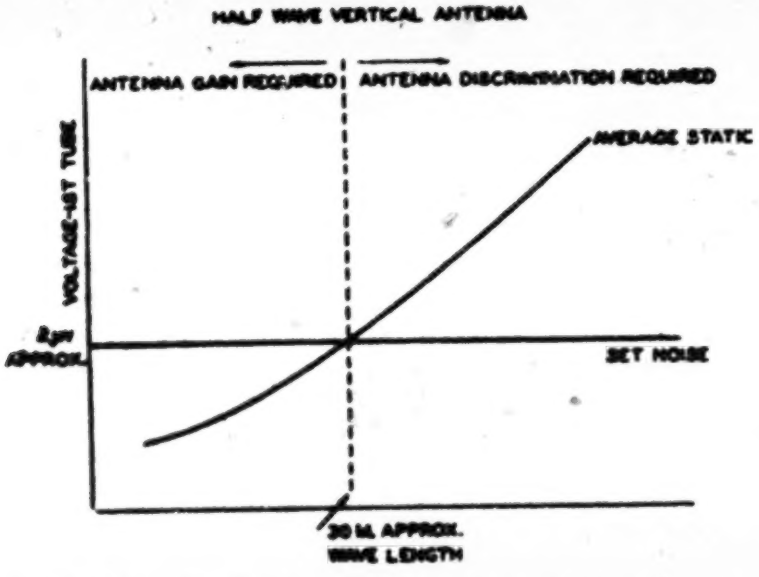


Fig. 1—Relative distribution of static and set noise with wavelength.

coupling circuits. Likewise, we have plotted the circuit noise delivered to this same tube as a function of wavelength. The fact that these curves intersect is of importance.

At wavelengths considerably below the point of intersection, a weak signal falls into the level of the set noise. Increased signal output from the antenna is desirable to override this noise. It is evident that static reduction through directional discrimination is of little use in this region, therefore an antenna having directional properties but possessing no marked gain in output over a simple nondirectional antenna has no merit. At wavelengths considerably above the point of intersection, static reduction through directivity is of utmost importance, while a gain in antenna output would be of little value if it meant a gain in static as well as in signal. It is interesting to observe, however, that a

sufficient reduction of static through directivity would lower the whole static curve until it lay below the set noise curve. Such being the case, signal gain would again be required.

The above arguments are intended to show that, at the shorter wavelengths, receiving antennas should be designed for a gain in signal output. At the long wavelengths, directive discrimination in reception is the major requirement. In contrast to this, a transmitting antenna has no such wavelength eccentricities. Its purpose is always to lay down at the receiving point as great a field as possible. We must not forget, however, that the time is near when more attention should be paid to marked directive discrimination in transmitting antennas as a means of reducing interference between congested communication channels.

While set noise and static are at times important factors in limiting successful short-wave communication, fading practically always presents varying degrees of annoyance. It is really surprising how much fading can be tolerated without radically affecting speech intelligibility, but for services such as high-grade program transmission where naturalness is also important vast improvements are required; consequently much attention has been, and is being, paid to this phase of the problem.

Increasing the Signal Output of Receiving Antennas

Under conditions of optimum output impedances, the magnitude of signal developed at the receiving antenna load is simply a function of



Fig. 2—Effects of antenna directivity.

the ratio of the effective induced voltage to the effective antenna resistance. The term effective induced voltage is used, as attention must be directed toward proper phasing, where the antenna dimensions are an appreciable part of a wavelength or more. Usually at short waves, the effective resistance is almost entirely the resistance equivalent of the reradiation losses. This resistance can be lowered through directivity, a simple example of which can be illustrated with the aid of Fig. 2.

If we can conceive of a point source of radiation at *A*, equipotential

radiation surfaces would be spherical in shape and symmetrically disposed around *A*. The field intensity at point *B* would be unaffected if we had some means of avoiding radiation through the unshaded half of the sphere, with a consequent saving of half of the radiated energy. If instead of saving this energy we added it to the shaded side, the energy available at *B* would be doubled. This is a simple explanation of the effect of directivity in the transmitting case. The receiving case is quite similar.

If the transmitter is at *B*, the energy available at *A* is diminished by reradiation losses. If we avoid reradiation through the unshaded half of the sphere, the radiation equivalent resistance is halved and the load energy will be doubled, after rematching the load to the antenna impedance.

With this knowledge of the usefulness of sharpened directivity, the designer is tempted to carry it to an extreme. The degree of directivity that may be beneficially attempted is, of course, limited by the variation in the apparent direction of wave arrival. For transatlantic, 16-meter signals over a daylight path, the horizontal plane angular variation, at New York has been[4] measured, by observing phase differences between spaced antennas, to be some 5 degrees or less, but apparently random throughout this range. Over a combination path of darkness and daylight, a horizontal angle variation considerably greater than this magnitude is frequently observed.

In the vertical plane, the variations in the apparent directions of arrival are considerable and also random. On rare occasions, angles as high as sixty degrees from the horizontal have been recorded. A sharp low angle antenna may well be expected to decrease in output as the angle of the wave direction becomes high.

Knowing that the interpretation of wave directions, by means of observed phase differences between spaced antennas, might be complicated if multiple waves of varying angles were present, two vertically polarized test antennas were built having optimum response at 27 degrees and at 6 degrees from the horizontal, respectively as shown in Fig. 3-A. These angles were experimentally obtained from airplane measurements. Fig. 3-B, which has been smoothed out for publication, is characteristic of about 80 per cent of the comparative data obtained on these two antennas, as measured by automatic signal recorders. Examination will show that, very frequently, the high angle antenna increases in output as the low angle antenna loses, or vice versa, indicating that the waves are varying in their vertical angle. Similar methods

[4] H. T. Friis, "Direction of propagation and fading of short waves," Proc. I.R.E., May, 1928.

have also cross-checked the horizontal plane movements previously mentioned.

Where it is planned to design a single fixed antenna for a particular service, the antenna should be sufficiently broad in its directivity to include most of the directional variations in signal arrival that may be encountered. In such cases, we have adopted the policy of simultane-

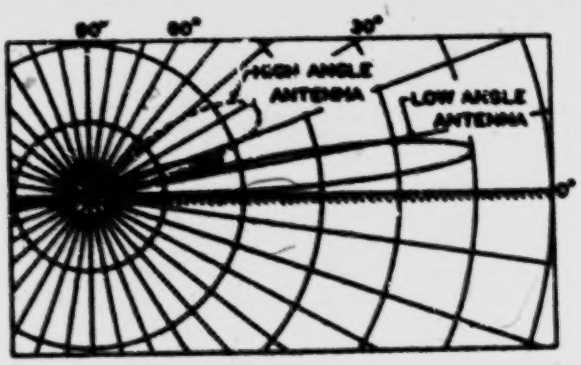


Fig. 3a—Comparative directive diagrams of a high and a low angle antenna.

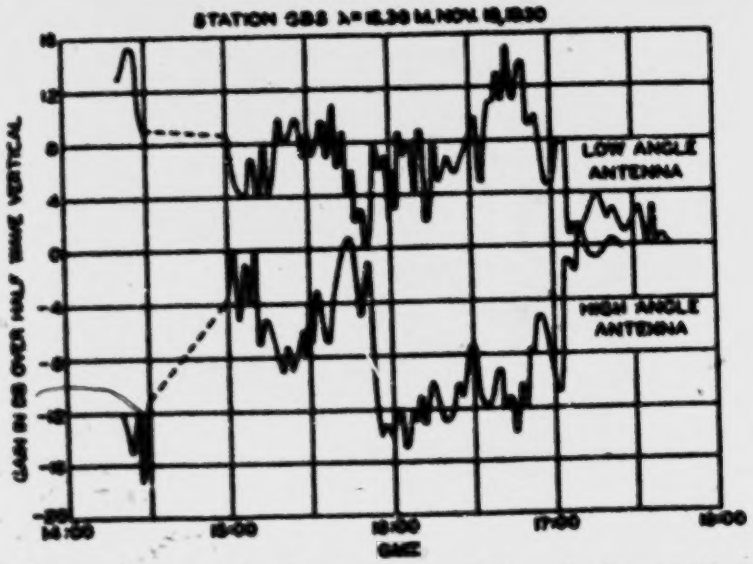


Fig. 3b—Comparison of signal outputs of a high and a low angle antenna.

ously comparing the signal outputs of various size antennas through the measurements of automatic signal recorders over long periods. A photograph of one such signal recorder is shown in Fig. 4.

Several of our test antennas have proved to be too sharp. On occasions, their output exceeded that of any of the smaller, less directive antennas, but when averaged over long intervals of time, they proved to be deficient. At first, we tried to avoid putting too much weight on

gain data obtained when signals were normally very strong but long experience seems to show that wave direction variation has little correlation with the field strength of signals.

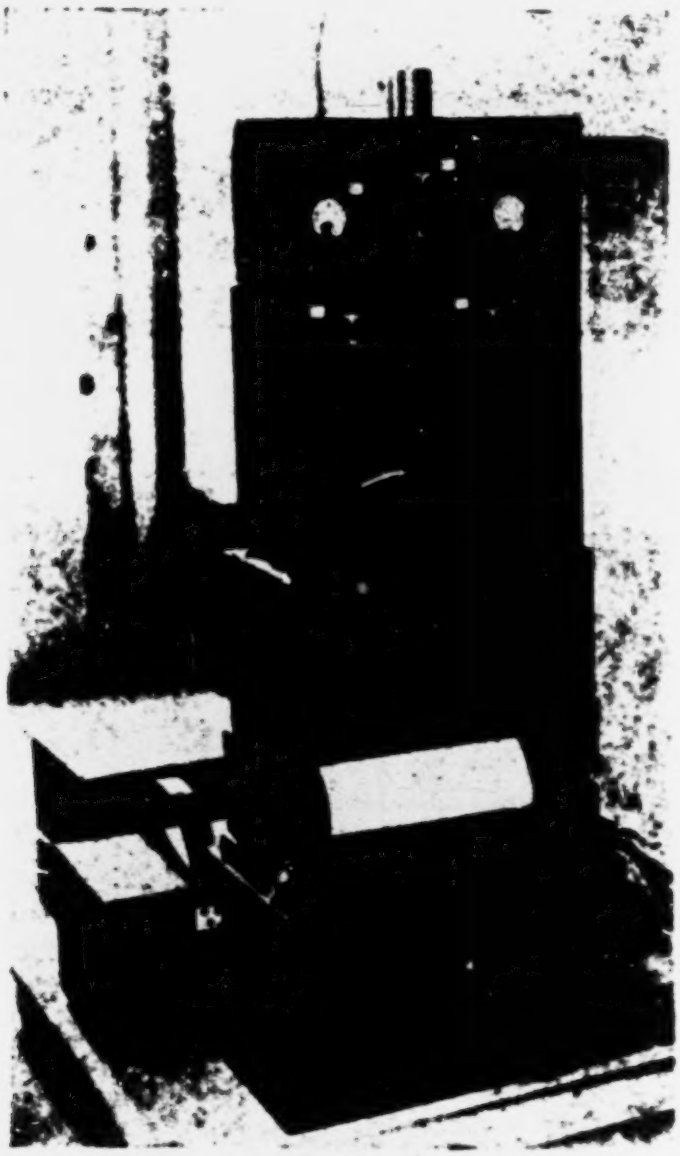


Fig. 4—An automatic signal recorder.

Static Reduction

Referring again to Fig. 2, assume that point A, receiving from B, is surrounded in all directions by static of uniform intensity. If A is made responsive only in the shaded directions, half of the static appears, at first, to be eliminated, but we must remember that, by previous argu-

ments, the static output from the shaded region is doubled; thus the over-all static output is the same. For uniform distribution, the static output level is independent of the degree of directivity, provided that impedance matching between the load and the antenna is always maintained. We see, therefore, that the improvement in signal-to-static ratio in this case is the same as the signal improvement alone.

If static were always uniformly distributed about an antenna, the problems of signal gain and improvement in the signal-to-static ratio would be synonymous. The fact that short-wave static is usually highly directional puts an entirely different aspect on the problem. If, in Fig. 2, the static came from a direction included in the unshaded portion of the characteristic, the improvement in the signal-to-static ratio would be infinite. In a receiving antenna, therefore, emphasis must be placed on the deep suppression of response in other than the favored direction.

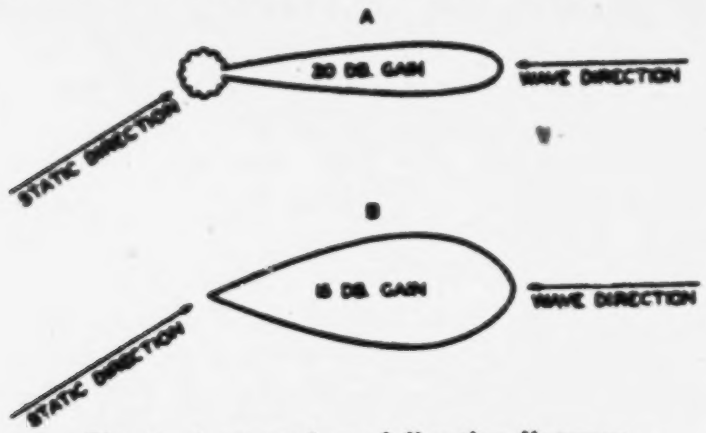


Fig. 5—A comparison of directive diagrams.

Fig. 5 is intended to illustrate the case described. The antenna characteristic 5A, having a signal gain of 20 decibels over a nondirectional antenna, does not accomplish deep rejection in other directions. It follows, therefore, that the better discriminating characteristic 5B would give a vastly better signal-to-static ratio, in spite of a smaller signal gain.

Fading Reduction

Many schemes for counteracting fading are in use and have been suggested. These include compensation for fading through automatic control of the receiver gain, the automatic selection of the best of several antennas, single side band with an unvarying locally supplied barrier, etc. All of these systems have merit, but are not a complete cure for the very prevalent selective type of fading, where several depressions may exist within a frequency band width of speech magnitude.

Under certain conditions, selective fading can be combatted through antenna directivity, but it is not without its difficulties in attainment. This is a direct attack on the multiple path source of the evil, eliminating a cause which makes fading selective with frequency. At times, very marked fading reduction has been obtained by this means.

Economics of Receiving Antennas

We have indicated briefly that the receiving antenna system has an important bearing upon all the major factors which are limitations in the present short-wave art. As long as these improvements can be effected in the receiving antenna system at a cost less than, for instance, a corresponding increase in transmitter power, concentration on the development of antenna design is well warranted

One often hears the question whether one type of directive antenna is better than some other type. The answer usually depends on an economic comparison rather than an electrical one. The sharpness of directivity, the gain, etc., are determined by existing conditions. Numerous types of antennas can be designed to meet these specifications, therefore it is evident that the final selection is often based on over-all costs.

In Part 2 of this paper an antenna system will be discussed which is the result of an attempt to produce an effective antenna at a cost more favorable than the types we have been accustomed to use up to the present time.

PART 2—LONG WIRE ANTENNAS

Types of Directive Antennas

Directive methods, employing a finite number of spaced elements of specific phase and amplitude relations, have been known for a long time. Most of the more recent innovations, in this form of antenna, have pertained to the methods whereby, in their practical applications, these phases and amplitudes have been achieved. Considerable use has been made to date of such antennas, but they are quite expensive in their larger sizes and often their frequency range is very limited. As a result of these frequency restrictions, the radiotelephone receiving station at Netcong, N. J., employs ten[1] antennas, all differing in their design frequency but having the same favored direction toward England.

For some time, it has been appreciated that if it were possible to

[1] A. A. Oswald, "Transoceanic telephone service—short wave equipment," *Bell Sys. Tech. Jour.*, April, 1930.

substitute a single directive antenna, having frequency characteristics sufficiently broad as to cover the above mentioned ten channels, a very large economic saving could be effected. Development work was undertaken which has not only resulted in an antenna of considerable frequency latitude, but this new antenna structure is actually less expensive than a single, equally effective unit of the previous type. The remainder of this paper will be devoted to a discussion of various applications of this form of antenna.

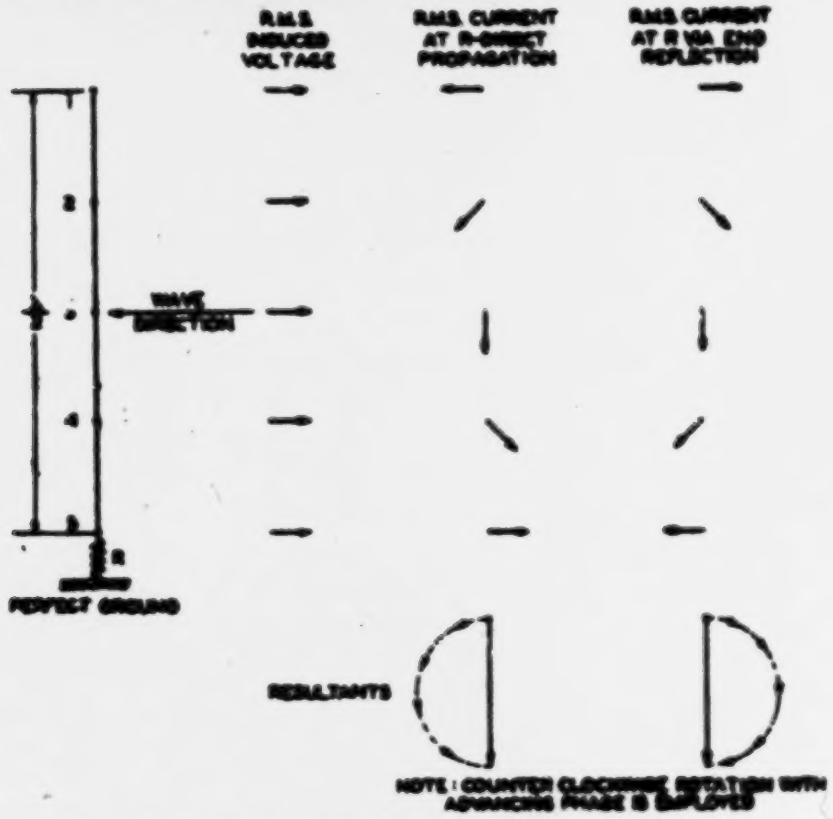


Fig. 6—Vector relations in a half-wave vertical antenna.

Principles of "Tilted" Wire Antennas

The elementary principles underlying "tilted" wires can be explained more readily by presenting a physical picture, through the use of r-m-s vector representation, rather than through a more or less cumbersome mathematical treatment. The vector representations that follow are not rigorous but they serve to convey quickly the ideas under consideration and give results which are in sufficiently good accord with the complete mathematic analysis.

As we increase the length of a simple vertical antenna exposed to horizontally propagated waves, always rematching impedances by

varying the load at its base, we obtain increases in the load power up to the point where the antenna wire length reaches one-half wavelength. The vector representation of this one-half wavelength case constitutes Fig. 6.

The first column of vectors represents the phase of the induced voltages, assumed to be lumped at points 1 to 5. The second column of vectors indicates the phase of the directly propagated currents arriving at R and due to each lumped voltage. The phase changes are due to the varying intervals of time required to traverse the intervening path.

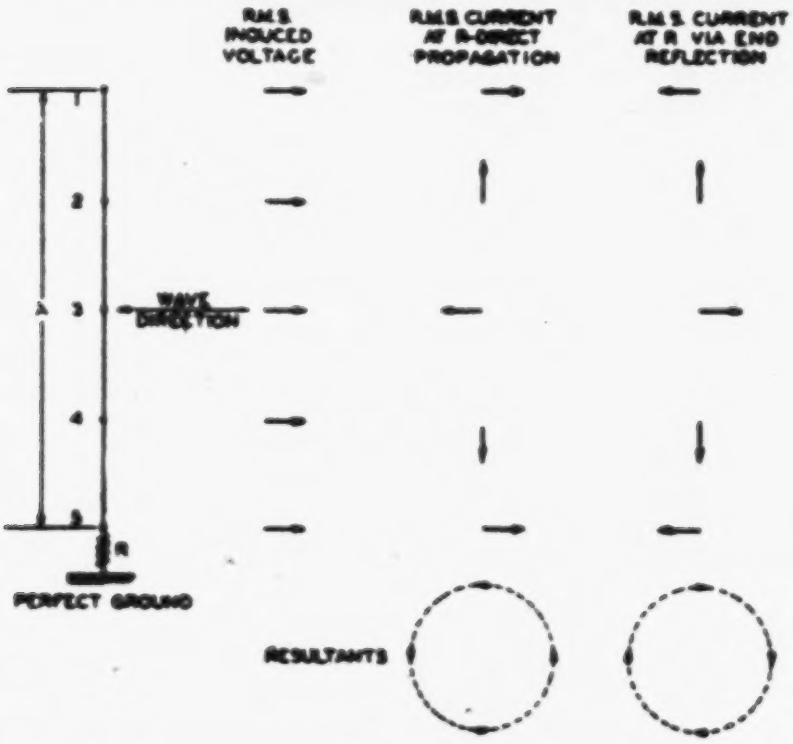


Fig. 7—Vector relations in a one-wave vertical antenna.

Likewise, the third column represents the current reaching R by way of the open-end reflection where a 180-degree phase change occurs. Summing up either column of current vectors, we trace a semicircumference and the resultant is a diameter. Had the antenna wire been slightly longer, the circumference would have been further closed and the resultant smaller. Fig. 7 illustrates an extreme case where the currents in R are zero for the vertical antenna length of one wavelength. Analyzing these vectors, we establish an important principle, as follows:

The length of a straight antenna wire is an optimum value, for currents directly propagated to the load, when the elementary currents due

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to voltages induced in small lengths at the two wire extremities are opposite in phase at the load, provided that this does not also occur for intermediate points. This statement has been restricted to the directly propagated currents since, in what follows, we shall, practically always, dissipate the currents propagated to the far end in appropriate terminating impedances. In many of the diagrams, the load currents which would arrive from open-end reflections have been included merely as of general interest.

The above stated principle permits us to remedy the null situation of Fig. 7 by tilting the wire as shown in Fig. 8. Notice that point 1 has

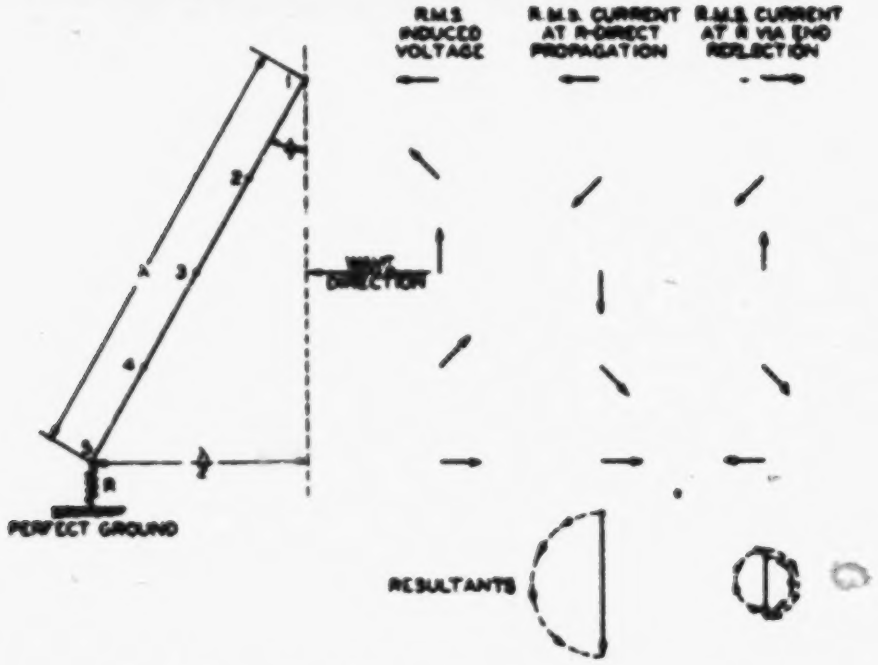


Fig. 8—Vector relations in a tilted wire antenna.

been advanced into the wave propagation so that, at any given instant, point 1 is later in phase than for instance, point 5. The directly propagated currents of Fig. 8 trace a semicircumference and, therefore, the wire length[6] appears to be an optimum for the tilt selected.

For any wire tilt angle, there exists a wire length which will trace a semicircumference similar to the above. This occurs when the tilt is such that the wire length is one-half wavelength longer than its projection upon the wave direction of propagation. Using appropriate tilt

[6] For rigid accuracy in determining optimum dimensions, a small correction must be applied to these rules. This correction occurs in cases where, upon changing the wire tilt angle, the rate of change of induced voltage is comparable to the rate of change of load current as described above.

angles, as the wire length increases, output gains are achieved through increased effective induced voltage in the wire. Still further gain in output is available through the increasing directivity that is bound to result from the increasing dimensions

One of the chief features of the tilted wire antenna is that in its longer lengths it is effective over a broad range of frequencies. This is illustrated by Fig. 9 which is a plot of the wire length versus the tilt angle utilizing the above mentioned rules. For example, if the antenna were designed for a frequency such that the wire was ten wavelengths long but it was used at another frequency where the wire length was only eight wavelengths, Fig. 9 shows that the inaccuracy of tilt angle

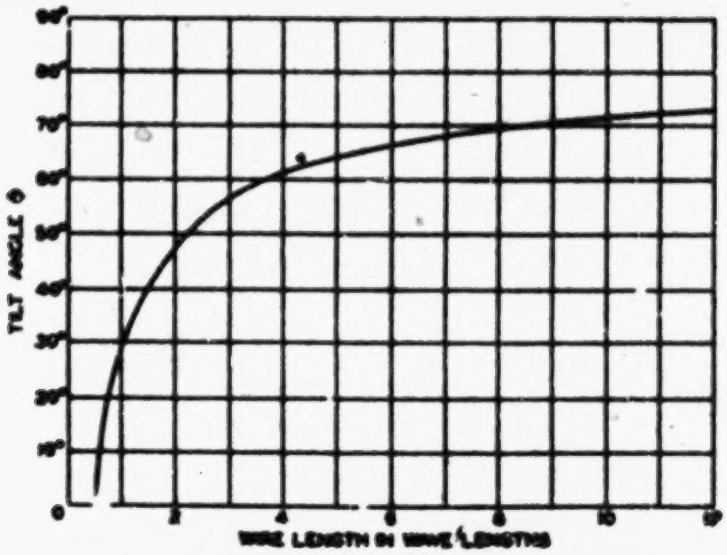


Fig. 9--Optimum tilt angle for long wires.

would be only about two degrees, which in most cases is inappreciable. As we shall see later, even this inaccuracy can be compensated by another wire in combination having an opposite trend.

Broad Frequency Range in Arrays

As is true for any antenna, the tilted wire may be used as an element in all the usual forms of arrays. Successful experimental antennas have been constructed consisting of a succession of tilted wires disposed in broadside relation, in the line of transmission and also stacked one above another. Some of these arrangements confine the effectiveness of the resulting antenna to a single frequency. Appreciating that one of the principle features of the tilted wire was its effectiveness over a broad frequency range, we have particularly stressed the development of

those combinations of tilted wires which would not place restrictions on this frequency range. One such combination is discussed in the following section.

The Inverted V

The combination of two tilted wires to form the inverted V is shown in Fig. 10. The directional characteristics are appreciably improved with a consequent increase in signal output; also, the far end of the antenna becomes accessible for termination purposes, near the ground. These terminations will be discussed later. The inverted V requires no more supporting structure than the tilted wire, therefore its additional cost is very small where the land is available. Fig. 10 is a vector picture indicating that the two elements of the inverted V add in proper phase relation.

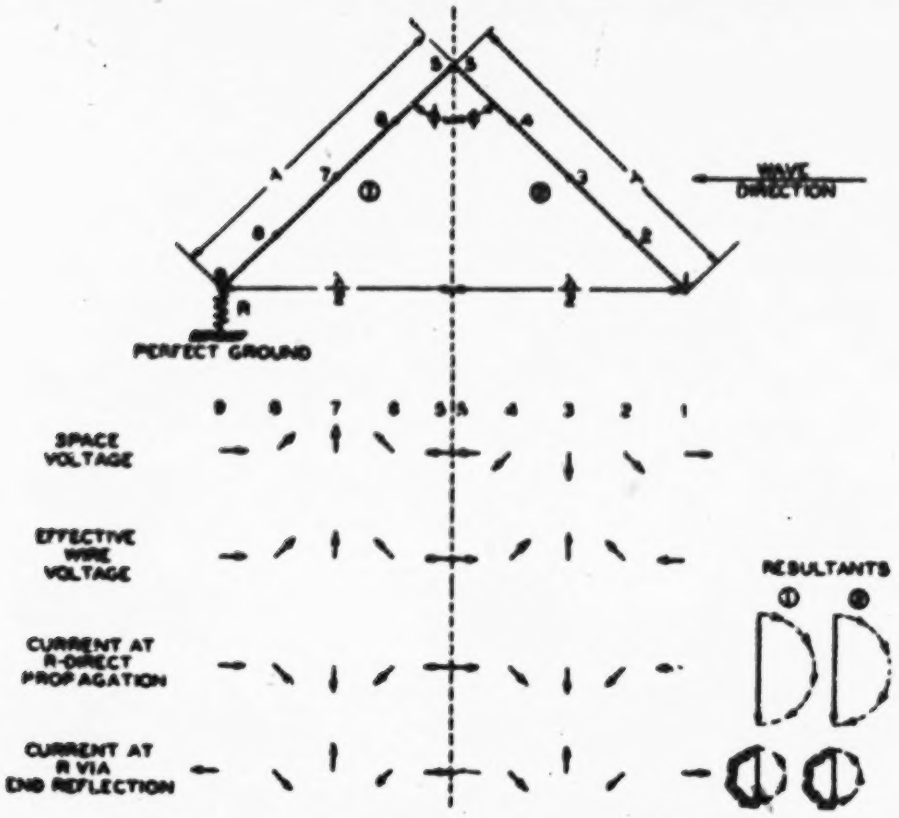


Fig. 10—Vector relations in an inverted V antenna.

In connection with Fig. 9, it has been mentioned that the small inaccuracies in tilt angle, due to departures from the design frequencies, can be counteracted by another wire in combination having an opposite trend. The inverted V of Fig. 10. is an example of one such possible

arrangement. Since the tilt angle error is opposite in direction for each leg of the V, in combination, their optimum direction of response will remain unaltered. This will be illustrated by calculated directive diagrams which will be given later.

Asymmetrical Directivity Through Far End Terminations

Where it is desired to make an antenna responsive to signals in a given direction but to discriminate against signals in the opposite direc-

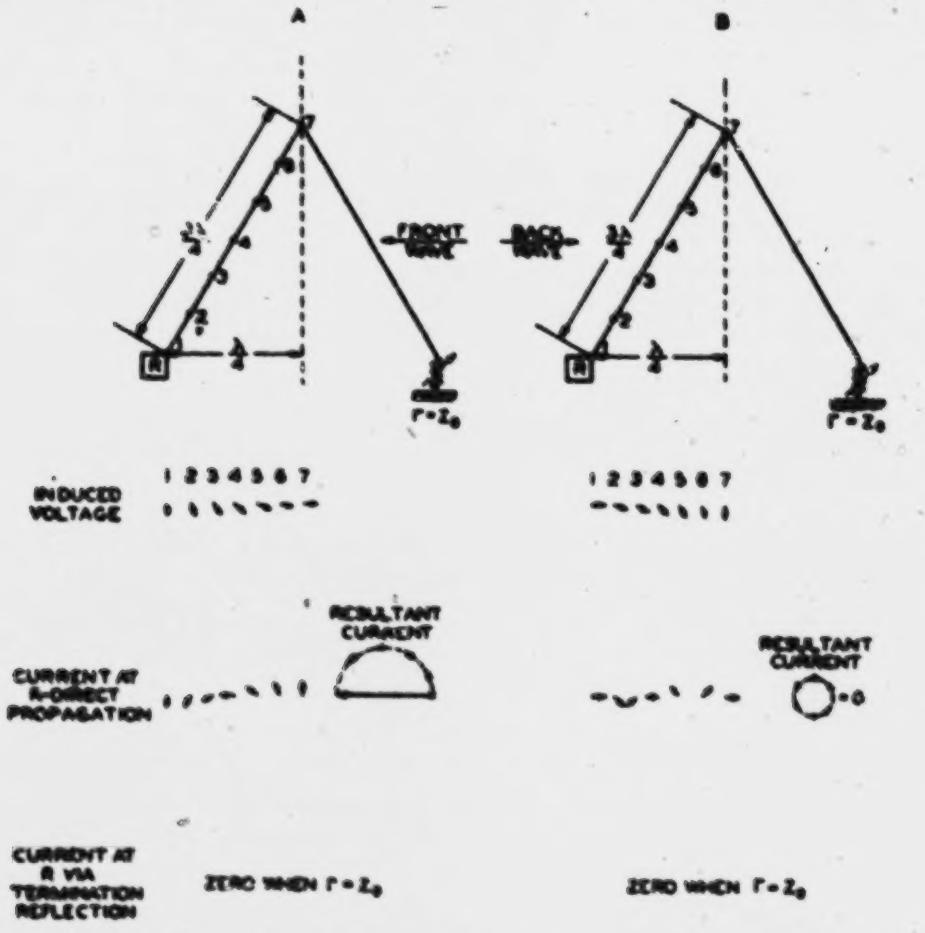


Fig. 11—Vector relations in an inverted V antenna—asymmetrical directivity.

tion, reflector systems are often employed. These reflectors may be parasitic or they may be directly connected to the receiver through apparatus controlling their phase and amplitude relations. Our experience has shown that reflectors may be employed in connection with the type of antenna under consideration for the purpose of obtaining unilateral directivity. However, the use of reflectors restricts the possible frequency range, as they only function efficiently at specific spacings in

relation to the wavelength used. For this reason, reflectors will not be discussed in this paper, although they are employed where a broad frequency range is not essential.

Tilted wire antennas and their combinations are particularly adapted to obtaining directional asymmetry through proper terminations of the end remote from the receiver. A simple example is illustrated in Fig. 11.

The end of the inverted V remote from the receiver *R*, in Fig. 11, is so terminated as to absorb signals without reflections. In other words, a

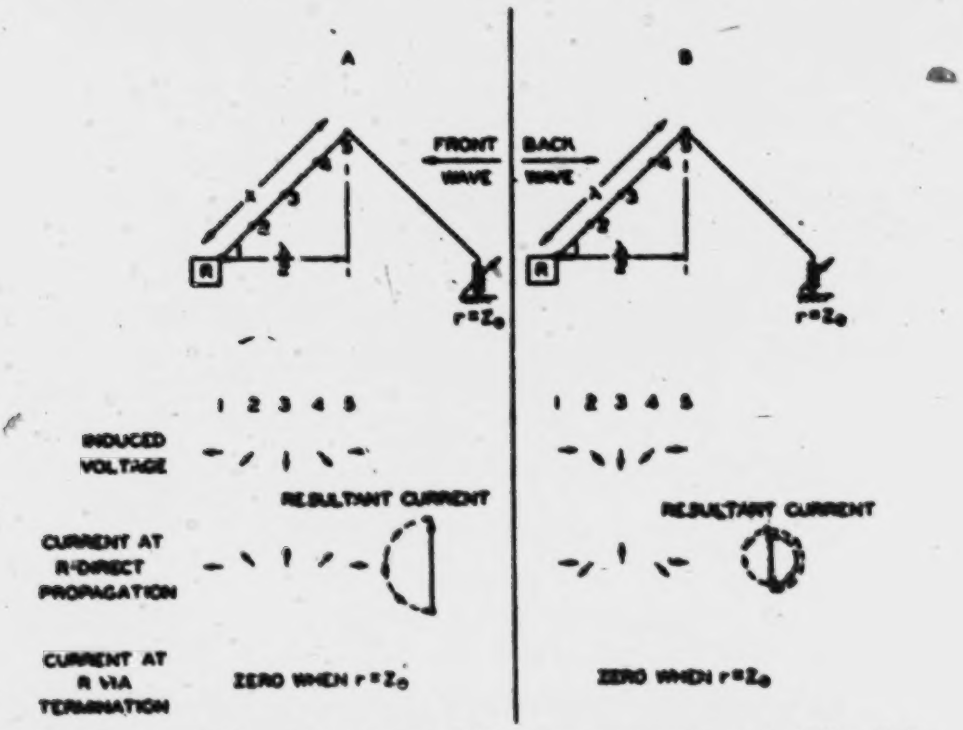


Fig. 12—Vector relations in an inverted V antenna—asymmetrical directivity.

termination equal to the antenna characteristic impedance is employed. Only the vectors for one leg of each of the inverted V's have been drawn, as the second leg is simply a reproduction of the first, and add directly thereto, after all phase relations have been determined.

In Fig. 11A, a wave from the right produces elementary load currents which trace a semicircle, as previously discussed. Note that when the wave arrives from the left as in Fig. 11B, the phase change is more rapid and a closed circle is traced making the resultant zero, thus we have achieved an infinite front-to-back ratio. It can be shown that this advantageous condition exists for tilted wires where the wire length of each element is an odd integral multiple, greater than one, of one-

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quarter wavelength, provided that the previously mentioned optimum tilt, in relation to the wave direction, is maintained.

At first glance, it might appear that the frequency range is restricted, since the above rule is limited to certain wire lengths expressed in wavelengths. The most disadvantageous case exists when the wire length is an even integral multiple, greater than two, of one-quarter wavelength. Fig. 12 illustrates one such case, the wire being one wavelength long and at optimum tilt. It will be observed that the front-to-back ratio is not infinite but there still exists some directional discrimi-

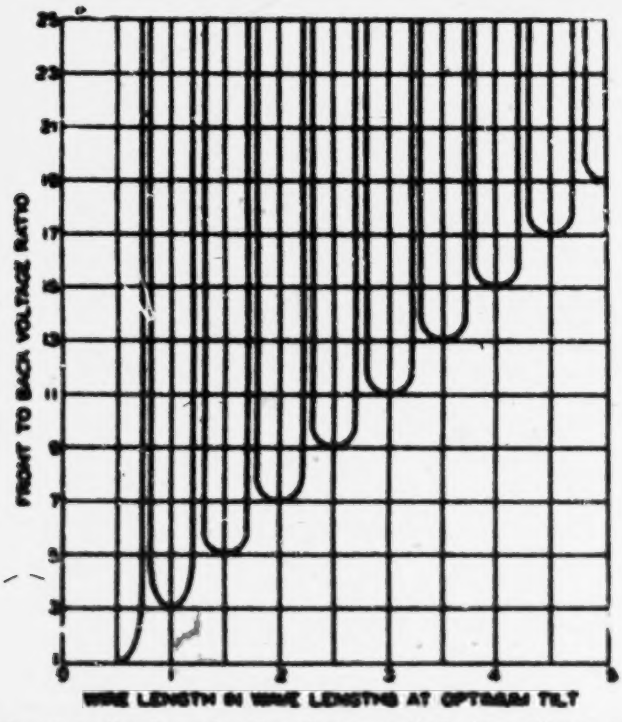


Fig. 13—Front-to-back ratios for characteristic impedance termination.

nation, due to the fact that the back wave has resulted in the elementary currents tracing one and one-half rotations, thus obtaining partial cancellation. It is important to notice that longer wires would result in an increasing number of rotations and the resultant current of the back wave would become smaller and smaller as compared with the resultant of the front wave. This is a further argument for the use of long tilted wires. The calculated front-to-back ratios obtained with characteristic impedance terminations for various lengths of wires at optimum tilt are plotted in Fig. 13.

A very interesting feature about terminations is that, provided we are willing to make slight readjustments in their value, it is possible

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to obtain infinite front-to-back ratios at all frequencies within range. This is accomplished by cancelling the residue of back signal by means of a small reflection from the end termination obtained by departing slightly from the characteristic impedance adjustment. It can be shown that this results, for wires which are in length an even multiple, greater than two, of one-quarter wavelength, when the termination is the characteristic impedance times the cosine of the angle made by the wire with the direction of wave propagation.

For long wires, the above readjustment is very small. As an example, a ten-wavelength wire is properly tilted when it makes an angle with the direction of wave propagation whose cosine is 0.950. Thus, only a five per cent reduction in the termination from the characteristic impedance value will give an infinite front-to-back ratio.

In practice, we usually adjust a termination to a value which is a compromise between the above value and the characteristic impedance This gives very favorable front-to-back ratios at any frequency within the range of the antenna, particularly in the case of long wires.

Theoretically infinite front-to-back ratios have been mentioned several times in the preceding discussion. It is an experimental fact that where very minute adjustments can be made in both the resistive and reactive components of the termination impedance, the front-to-back signal voltage ratio is only limited by the rigidity of the antenna elements in space. Voltage ratios in excess of 1000 to 1 are readily obtained, although such extremes are seldom warranted in practice. This deep depression can be "steered" through a considerable range of directions largely through changes in the reactive component of the termination impedance, the resistance alteration required being small. This permits a high degree of discrimination against many specific cases of interference in the rear quadrant of the antenna.

The Diamond-Shaped Antenna

In terminating inverted V antennas to ground, trouble has been experienced due to the instability of the ground contact resistance during varying weather conditions. In addition, the signal "pick-up" in the connecting leads was not always small compared with the antenna signal response in directions of antenna minima. These difficulties were avoided by terminating to the center point of a straight wire, substantially a half wavelength in total length, lying perpendicular to the favored wave direction.

As is well known, a quarter wavelength open-ended element appears to be a very low resistance when measured between its terminal and ground or another similar element. Two such low resistance quarter

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wavelength elements are effectively in parallel in the above arrangement and the center-tapped symmetry substantially balances out the effect of voltages induced in these elements.

Variations of the above type of artificial ground have been used in connection with inverted V antennas but, with few exceptions, they have required readjustments as the frequency was altered. A more satisfactory arrangement from several points of view is the double-V or diamond-shaped antenna shown in Fig. 14. This provides a balanced arrangement eliminating the necessity of a "ground" connection; furthermore, it does not place any frequency limitation upon the system.

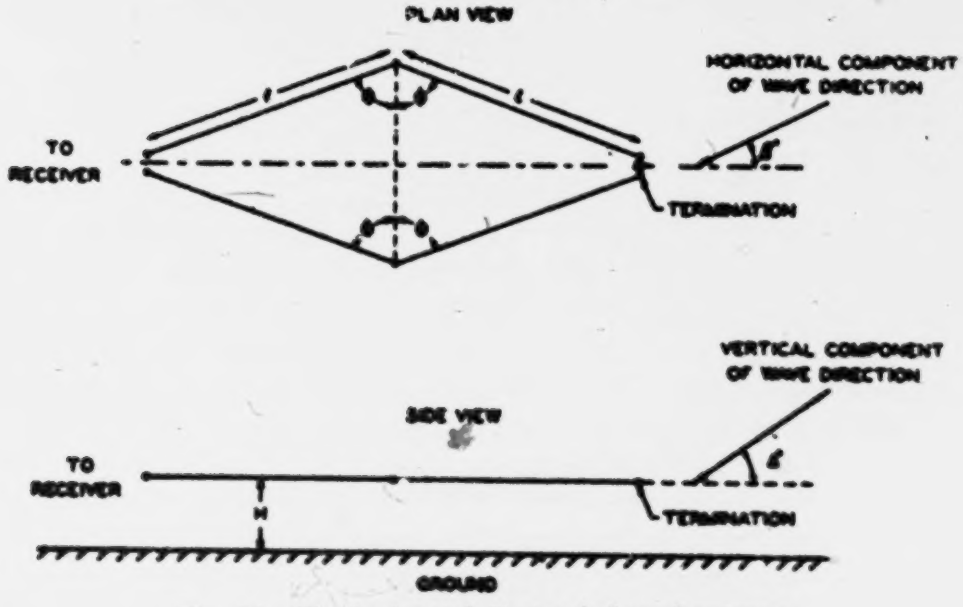


Fig. 14—The horizontal diamond-shaped antenna.

The antenna in Fig. 14 may be used with its plane either vertical or horizontal, being responsive, respectively, to vertically or horizontally polarized waves. It has found its greatest application in its horizontal form, however, due to reasons enumerated below.

(a) The supporting structure in its horizontal form is less costly, since only four relatively short poles are required.

(b) The inherent high angle directive characteristics of horizontal antennas discriminate against ignition, power, and other noises originating near the ground.

(c) The solid directive diagram of the diamond-shaped antenna is sharpest in the plane of the antenna. Since the direction of wave propagation is more stable in the horizontal plane, it is desirable to have the plane of the antenna horizontal.

(d) The directivity of the horizontal diamond-shaped antenna can be aimed, to some extent, at the most desirable vertical angle merely by altering the "tilt" angle ϕ of the antenna.

(e) The performance of the horizontal antenna is stable with varying weather conditions, since horizontally polarized waves are less affected than are the vertical by varying ground constants.

The use of the antenna horizontally, in the usual short-wave range, assumes that the strength of horizontally polarized waves are at least as great as are the vertically polarized components. Several observers have reported them more so, but the experience of the writer has been that there is little choice where horizontal and vertical antennas, having the same degree of directivity and optimum direction, are compared.

Up to this point in this paper, the attempt has been made to present simply a broad picture of some of the applications of long tilted wires to antenna design. It now seems worth while to give in somewhat more detail a sample of the design methods employed and the performance measurements on one typical form of antenna; accordingly a medium size horizontal diamond-shaped antenna has been selected.

The Horizontal Diamond-Shaped Antenna

In calculating the directive diagrams of the horizontal diamond-shaped antenna, the antenna wires have been assumed to be without resistance. As long as we are contented in knowing only the relative shape of the directive diagrams, this approximation is quite accurate and results in a tremendous simplification of the problem.

In all of the calculations, a perfect ground has been assumed. Fortunately, for horizontally polarized waves, variation in the ground constants do not radically affect either the amplitude or phase of the ground reflections, so that the following equations can be used as rough approximations even where imperfect ground conditions are encountered.

Vertical Plane Directivity

The vertical plane directivity of the horizontal diamond-shaped antenna is determined by three factors, i.e., the length of each leg, the "tilt angle" and the height above ground.

For the cases where the element length is an integral multiple of a half wavelength and where the far end termination is the characteristic impedance multiplied by the sine of ϕ (see Fig. 14), the equation for the vertical plane directivity over perfect ground has been calculated to be,

$$I_R = k\left[1 - e^{-j4\pi H \sin \Delta/\lambda}\right]\left[\frac{1 + \cos \Delta}{1 - \sin^2\phi \cos^2 \Delta}\right]\left[1 \pm e^{-j2\pi l \sin \phi \cos \Delta/\lambda}\right];$$

where, as shown in Fig. 14,

H = height above perfect ground in wavelengths.
Δ = wave angle from horizontal in the vertical plane
ϕ = tilt angle of elements.
l = element length in wavelengths.
k = proportionality factor.
I_R = receiver current.

Note: In the third bracketed quantity use, in the $\pm$ sign, $-$ when l is an even integral multiple of $\lambda/2$ and $+$ when l is an odd integral multiple of $\lambda/2$.

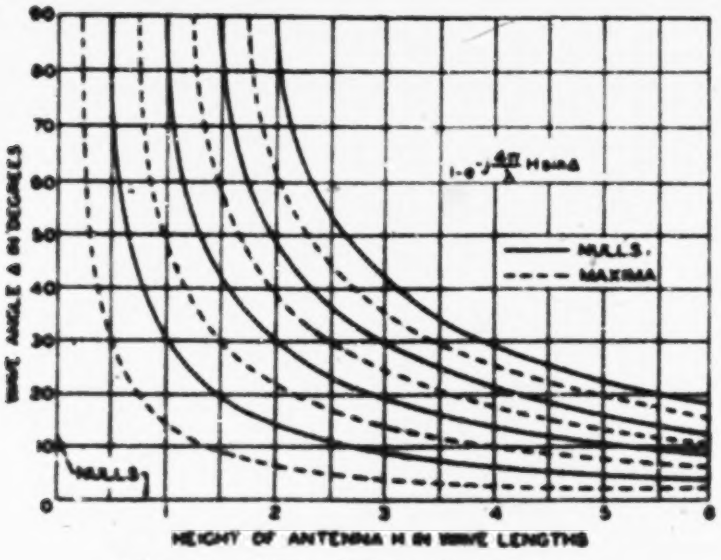


Fig. 15—Vertical plane design chart.

It will be noted that neither the length nor the tilt angle appears in the first bracketed term. It can be shown that this factor appears as a multiplier for nearly any type of horizontal antenna, accordingly the location of nulls and maxima for this factor are separately plotted in Fig. 15.

In the same manner the nulls and maxima of the product of the second and third bracketed terms have been plotted in Fig. 16 for an element length of four wavelengths.

The curves of Figs. 15 and 16 are design curves and their use can be illustrated by the following example: Measurements on the directions of wave arrival have indicated that the most usual directions are from 10 to 15 degrees above the horizontal. It is desired to construct a hori-

zontal diamond-shaped antenna for this reception, employing four-wavelength elements. Fig. 15 indicates that the most economical pole height for 15 degrees is approximately one wavelength. Now referring to Fig. 16, we see that the largest tilt angle, to accomplish this, is about

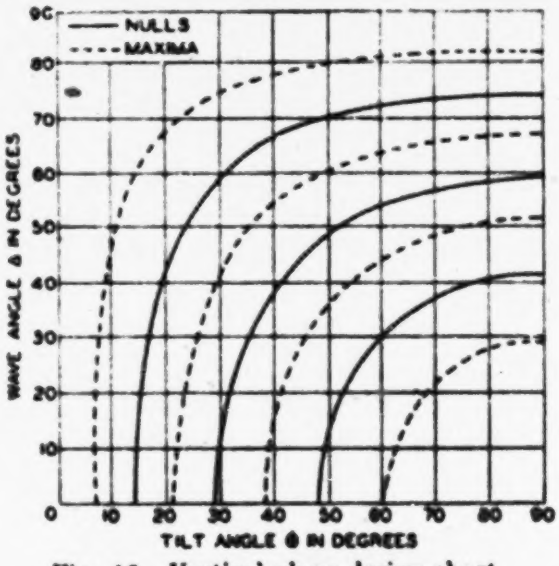


Fig. 16—Vertical plane design chart.

65 degrees. It is always desirable to use the largest possible angle of tilt to obtain the use of the largest lobe of the directive diagram.

Figs. 15 and 16 likewise give us the null points. These are seen to be 0, 30, and 90 degrees in Fig. 15 and 34, 57, 74, and 90 degrees in Fig. 16.

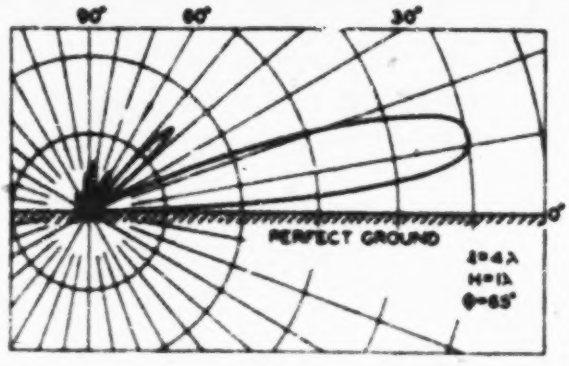


Fig. 17—Vertical plane directive diagram.

Using the above determined dimensions, the complete directive diagrams are calculated to determine whether a satisfactory result has been accomplished. Fig. 17 is the complete vertical plane diagram as calculated from the previously given equation. Should some undesir-

ably large minor lobe be present, it is often possible to suppress it by slightly changing one of the variables. A knowledge of the location of the null points, as given by Figs. 15 and 16, is a valuable guide in this accomplishment.

Horizontal Plane Directivity

Due to the cancellation effect of the reflections of horizontally polarized waves from a perfect ground, the horizontal plane diagram, for a horizontal antenna, is merely a point. The way to view directivity is properly in its solid form, but the calculations and plotted representations are somewhat laborious. The designer is in real need of knowing the horizontal width of the major lobe of the directional characteristic as would be seen from a plan view. This angular width, as measured between null points, is not altered by ground effects; therefore a useful simplification of the calculations may be had by ignoring the cancellation effect of the ground reflection. It should be pointed out that the amplitudes are slightly erroneous when this is done, but the null point locations are accurate. If this is done, we obtain the following equation:

$$I_R = k'\left[\frac{1+\cos\beta}{\cos^2\phi-\sin^2\beta}\right]\left[1\pm\epsilon^{-j2\pi l\sin(\phi+\beta)/\lambda}\right]\cdot\left[1\pm\epsilon^{-j2\pi l\sin(\phi-\beta)/\lambda}\right]$$

where, as shown in Fig. 14,

β = wave angle in horizontal plane.
ϕ = tilt angle of elements.
l = element length in wavelengths.
k' = proportionality factor.
I_R = receiver current.

Note: In the second and third bracketed quantities use, in the $\pm$ sign, $-$ when l is an even integral multiple of $\lambda/2$ and $+$ when l is an odd integral multiple of $\lambda/2$.

Fig. 18 is a plot similar in character to that of Fig. 16, giving the location of nulls and maxima in the same manner. In our previous example, vertical plane considerations indicated that a tilt angle of 65 degrees was desirable. An examination of Fig. 18 gives a rapid estimate of the approximate plan view of the directive diagram and Fig. 19 is the more complete plan diagram for this tilt angle. It will be noted in Fig. 18 that the lines indicating factor maxima and minima frequently intersect. This property can be utilized for the suppression of particular minor lobes of the directive diagram by a proper selection of the tilt angle.

Frequency Range

Previously, it was stated that the V form of antenna counteracts the slight tendency for a change in optimum direction when the fre-

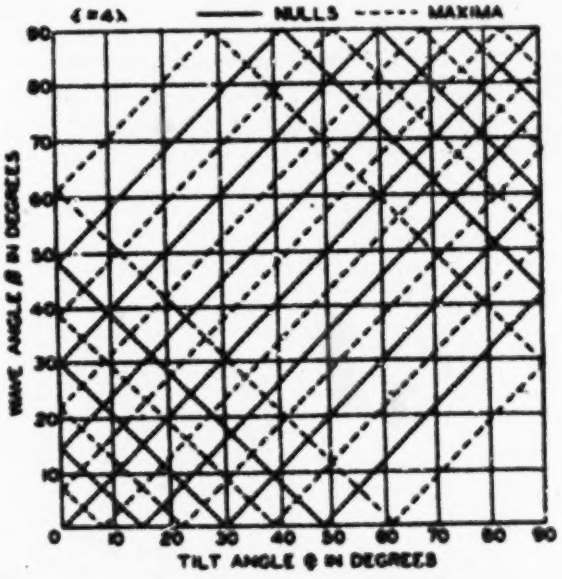


Fig. 18—Plan view design chart.

quency is altered. The correctness of this statement is verified in Figs. 19, 20, and 21. The linear dimensions and tilt angle were unaltered as the wavelength was varied over a two-to-one range. The optimum

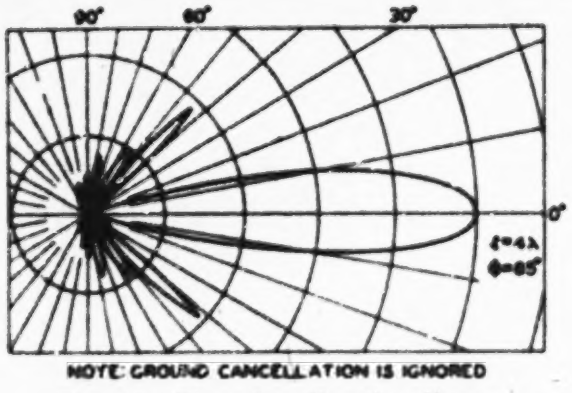


Fig. 19—Plan view directive diagram.

direction is maintained although, as would be expected, the directivity becomes less sharp as the wavelength is increased in respect to the antenna dimensions.

Due to the variability of the wave directions in the vertical plane, this desirable direction is not well defined. As the wavelength is in-

creased, a broadening characteristic counteracts the possibility of losing signal due to the optimum direction of the characteristic moving slightly upward.

Antenna Coupling Circuit

A two-wire transmission line has been used as the connecting link between the antenna and the coupling circuits at the receiver. With this arrangement, the circuits must be carefully balanced against ver-

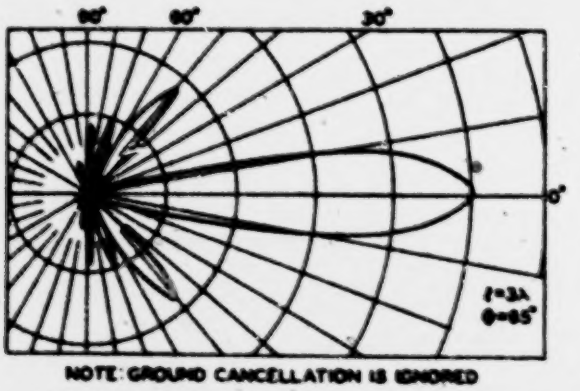


Fig. 20—Plan view directive diagram.

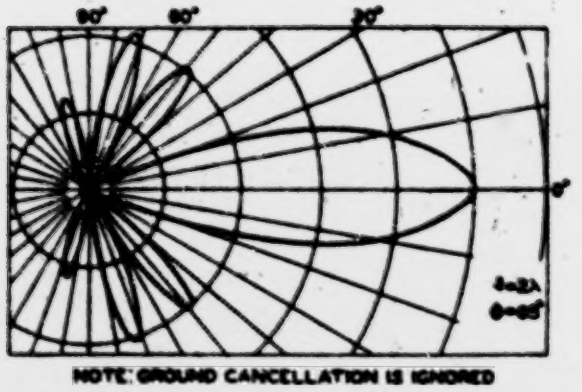


Fig. 21—Plan view directive diagram.

tical waves to obtain local noise reduction and to avoid reradiation losses from the transmission line. This is not difficult for a single frequency but if the coupling circuits are to maintain this balance for a range of frequencies, very careful designing of the coupling circuits is required.

The present practice is to place these coupling circuits in an elevated position directly at the antenna terminals to reduce the necessity for finical balancing adjustments. These circuits are connected to the receiver through a concentric pipe transmission line with its accom-

149 939

panying low loss, freedom from "pick-up," and substantial weather-proof construction. Multipeaked coupling circuits have been devised so that no readjustment is required over quite a frequency range.

Measured Performance

From the inception of our short-wave experience, we have been accustomed to compare the performance of antennas with a half-wave vertical antenna. The lower end of this standard of comparison is near the ground and connected to a coupling circuit in such a manner that matched impedances are realised. Although the antenna under consideration is intended for the reception of horizontally polarised waves, the same vertical comparison standard has been maintained.

As previously mentioned, automatic signal recorders of the type shown in Fig. 4, are connected to each antenna. This recorder indicates an integrated average signal during each ten-second period, thus removing the wide amplitude excursions due to fading. It is an interesting fact that, although the instantaneous fading of two antennas may be different, the average signal over ten seconds usually has corresponding rises and falls in amplitude. This effect is so marked that any possible inaccuracies in the timing axis are readily detected, when comparing records. To promote accuracy in amplitude comparisons, only corresponding peaks or hollows of the curves are used. It is obvious that the employment of steep sides of curves would put a premium on very accurate timing. The relative timing of recorders is usually very good, as their synchronous motors are run by the same a-c power supply. The relative signal strength accuracy of the recorders is better than one db.

The antenna reported in the following data is an experimental antenna, at Holmdel, N. J., shown in the photograph of Fig. 22. This picture illustrates the extreme simplicity of this type of antenna. The antenna dimensions are the same as those in the previously discussed directive diagrams when used at 16 meters. As has been said so many times before, the gain of the antenna over the standard may be expected to vary with the varying wave directions. The following data are the results of several hundred hours of tests, made at Holmdel, N. J., during the fall and winter months. Three different wavelengths were used with no alteration whatever in the antenna, its termination, or its transmission line coupling circuits. The standard of comparison, however, was always a half wavelength for the signal under test. It has been thought desirable to plot the gain data as the percentage of total time the antenna gain was above the indicated value in order to show the gain distribution with time. This summary of gains is given in Fig. 23.

I am indebted to a member[7] of our laboratories for an interesting variation which has been used in the application of this type of antenna to the transmitting problem. A simple terminating resistance is often



Fig. 23—An experimental horizontal diamond-shaped antenna.

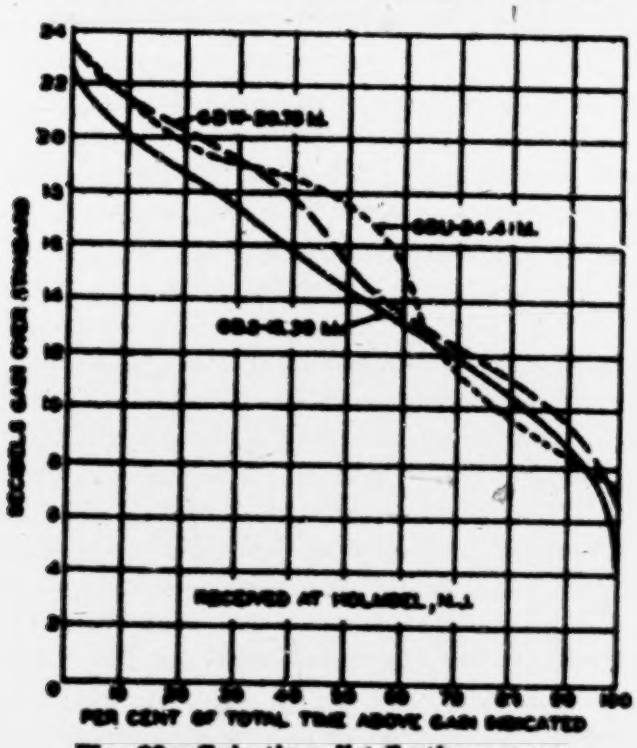


Fig. 24—Gain-time distribution curves.

undesirable in the transmitting case since it may be called upon to dissipate several kilowatts, in fact, that portion of the energy which would be radiated backward if no terminating resistance were employed. A

[7] R. J. Sterba, Bell Telephone Laboratories.

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long, two-wire iron transmission line shorted at the far end has been found to be one useful terminating load of the required dissipating ability.

The terminated diamond-shaped antenna possesses a broad impedance-frequency characteristic. This property may be augmented by reducing the characteristic impedance of the antenna. One convenient scheme for reducing the impedance is to employ several conductors in parallel in each leg of the antenna. The characteristic impedance may in this manner be dropped to a value for which matching iron wire lines are readily constructed.

The terminating load which produces the most desirable impedance characteristic does not necessarily produce the best front-to-back ratio. In the transmitting case, however, the deep directed nulls required in reception, to eliminate interference of some particular station, are not necessary. It is sufficient to reduce by 10 or more decibels the field in the back directions. Thus the modified diamond-shaped antenna may be employed as a unidirectional transmitting array accepting power over a two-to-one frequency range.

In conclusion, I should like to point out that the work described in this paper was possible only through the assistance, coöperation, and advice of many people in the Bell System, to all of whom I render my sincere thanks. In particular, I wish to mention Messrs. A. C. Beck and L. R. Lowry who supervised the construction and did most of the testing of the experimental models. Mr. H. T. Friis, not only contributed many suggestions and constructive criticisms of the work, but took steps to have developed apparatus which was essential for the automatic measurement of received signal levels.

DEFENDANT'S EXHIBIT 00

Proc. I.R.E. - Vol. 14 - Oct. 1926
pp. 675-688 (only pp. 675-681)

FIELD DISTRIBUTION AND RADIATION RESISTANCE OF A STRAIGHT VERTICAL UNLOADED ANTENNA RADIATING AT ONE OF ITS HARMONICS*

By
S. A. Levin and C. J. Young
(Radio Engineering Department, General Electric Company)

I. Introduction

Current and voltage distribution, electromagnetic field and radiation resistance are some quantities, among many, of interest in the investigation of an antenna. Their more or less complete and accurate determination is possible, mainly due to the works of H. Hertz[1] and M. Abraham.[2] The principles, given in these and other works, have here been applied to the investigation of an unloaded antenna consisting of a straight vertical wire radiating at one of its harmonics. The term "unloaded" is important. An antenna consists of a system of conductors, representing distributed capacities and inductances, which conductors are connected to one or more circuits with usually concentrated capacities and inductances. This is the general form of the loaded antenna. If the latter circuits are of negligible influence, or if no such circuits exist at all, then the antenna is unloaded.

Previously, similar calculations have been made by M. Abraham,[2] G. W. Pierce,[3] S. Ballantine,[4] H. Chireix,[5] and M. A. Bontch-Bruojevitch,[6] among others. Since the present article contains added information, its publication has been thought justified, particularly at a time when all data on short wave radio transmission are of interest.

The antenna may be grounded or not and, in the latter case, its lower end may be at any distance above ground. The in-

*Received by the Editor, January 13, 1926. Presented at the New York meeting of The Institute of Radio Engineers, September 1, 1926.

[1] H. Hertz, Ges. Werke, v. II.

[2] M. Abraham, Phys. Zeitschrift, v. 2, 1901, p. 329.

[3] G. W. Pierce, "Electric Oscillations and Electric Waves," New York, 1920, p. 135, particularly p. 181.

[4] S. Ballantine, Proceedings of The Institute of Radio Engineers, v. 12, 1924, p. 823.

[5] H. Chireix, "Radioélectricité," p. 5, 1921, p. 65; Bulletin Technique.

[6] M. A. Bontch-Bruojevitch, "Elektrichestvo," April, 1925, p. 228.

where n may be odd or even.
Then

$$e = \frac{4a}{cr_0}\cos\frac{2\pi}{\lambda}(ct - r_0)\cos(\beta\gamma\cos\theta)\sin\theta^{\frac{\cos(\beta\cos\theta)}{\sin^2\theta}}. \quad (13)$$

C. *Ungrounded Antenna Operating at Even Harmonics*—Similarly, when n is an even integer

$$e = -\frac{4a}{cr_0}\cos\frac{2\pi}{\lambda}(ct - r_0)\sin(\beta\gamma\cos\theta)\sin\theta^{\frac{\sin(\beta\cos\theta)}{\sin^2\theta}} \quad (14)$$

D. *Grounded Antenna*

$$e = -\frac{2a}{cr_0}\cos\frac{2\pi}{\lambda}(ct - r_0)^{\frac{\cos(\beta\cos\theta)}{\sin\theta}}, \quad (15)$$

where n is an odd integer, and the limits of integration are now zero and $\frac{\lambda_0}{4} = l$.

E. *Power Distribution Curves*—The numerical value of the Poynting vector[14] is $\frac{c}{4\pi}e^2$, where e can be obtained from the equations (13)(15). Since only relative values of this vector are of interest here, the factor $\cos\frac{2\pi}{\lambda}(ct - r_0)$ may be omitted in the evaluation of e^2, as at a given moment it has the same value at all points. If in a polar diagram the length of the radius vector, corresponding to the angle θ, is made proportional to e^2, then

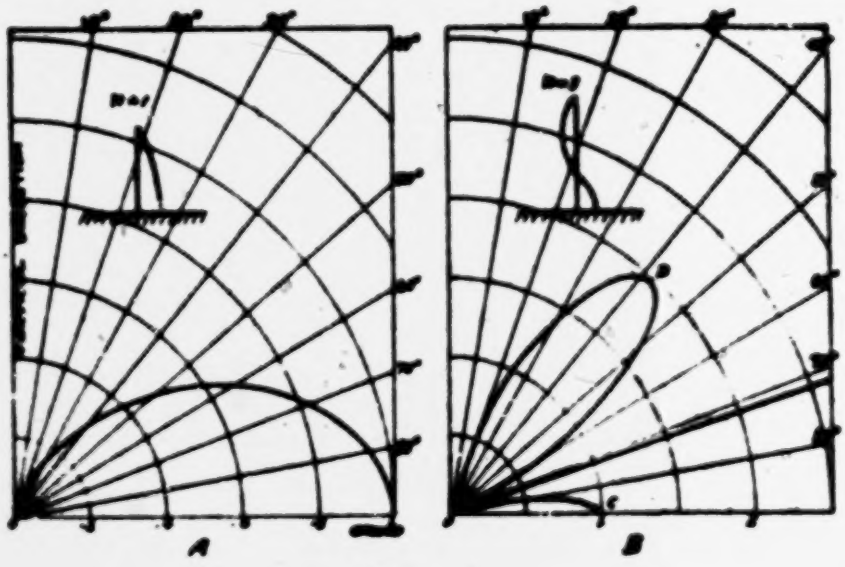


FIG. 5

[14] See for instance, Page, l. c.

1154-1155

DEFENDANT'S EXHIBIT PP

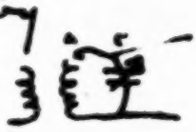
Friday, May 14 26

1. fine shower in early A.M. Clearing off later. Real hot. Y° sitting in U.Y. with two panels for Heising's Journal.

Wade came calls for Bruce. He used an antenna as

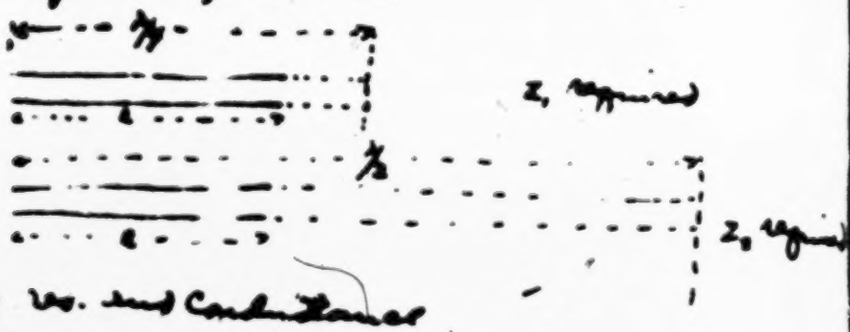


which is terminated by



and for a given freq. get normal resonant settings on the anti resonant circuit.

If he has a shortlocked wire system (less than ¼ λ) then (neglecting the manner in which the E.M.F. gets in) there will be resonance when his system is terminated by impedances which are equal to the impedances of such lengths of conductor as would make ¼, ¾, ¾ ..... oscillators. Or for the first two



and, neglecting res. and Conductance

$$Z_1 = -i\sqrt{\frac{L}{C}} \tan \frac{2\pi}{\lambda}\left(\frac{\lambda}{4} - l\right)$$ for all odd values of i will be $\tan \frac{2\pi}{\lambda}\left(\frac{i\lambda}{4} - l\right)$

$$Z_0 = -i \frac{\sqrt{\frac{L}{C}}}{\tan \frac{2\pi}{\lambda}\left(\frac{\lambda}{2} - l\right)}$$ for all even values of i will

$$\frac{1}{\tan \frac{2\pi}{\lambda}\left(\frac{i\lambda}{4} - l\right)}$$

And this series of impedances gives the ... type ... phenomena Bruce observed.

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DEFENDANT'S EXHIBIT QQ

2/16/28.

Sat #7 Filter switch closed 1 button pressed
$\frac{\lambda}{2}$ Vertical Coupling = N_A = 2.5/16 coil
α_1 (for 80 mA change) = 23 TU
α_2 (" 30 - 30 mA) = 89 TU
$\alpha_1 - \alpha_2$ = 23 - 89 = -66 TU

Vertical Vertical
Vertical Vertical

1λ tilt (toward osc.) . N_A = 1.5/16
α_1 (80 mA) = 26
α_2 (30 - 30 mA) = 89
$(\alpha_1 - \alpha_2)$ = -63

2λ > (toward osc.) N_A = 1.5/16 t
α_1 (80 mA) = 23½
α_2 (30-30 mA) = 88
$(\alpha_1 - \alpha_2)$ = -64½ } top of pole

α_1 (80 mA) = 23½
α_2 (30-30) = 88
$(\alpha_1 - \alpha_2)$ = -64½ } 1 meter from top of pole.

α_1 (80 mA) = 22
α_2 (30-30) = 88
$(\alpha_1 - \alpha_2)$ = -66 } 2 meters down

Page Tightly Bound

Continued

$\alpha_1 = 22$
$\alpha_2 = 88$
$(\alpha_1 - \alpha_2) = -67$ Tot. } 3 meters down.

α_1 (90 μA) = 20.5
α_2 (30-30 μA) 88
$(\alpha_1 - \alpha_2)$ −67.5 Tot } 4 meters down.

α_1 (80 μA) = 20
α_2 (30-30 μA) = 88
$(\alpha_1 - \alpha_2) = -68$ } 5 meters down

α_1 (80 μA) = $18\frac{3}{4}$
α_2 (25-25 μA) = 88
$(\alpha_1 - \alpha_2) = -69\frac{1}{4}$ } 6 meters down

Cont. 3 8/16/28.

4 λ ◇ N_A = 1/6 x. 1 button pressed.

α_1 (80 μA) : 22 3/4
α_2 (30-30 μA) : 87.5
$(\alpha_1 - \alpha_2)$ = -64 3/4
} 4 of pole

α_1 (80 μA) : 21
α_2 (30-30 μA) : 87.5
$(\alpha_1 - \alpha_2)$ = -66.5
} 1 meter down.

α_1 (80 μA) : 195
α_2 (30-30 μA : 87.5
$(\alpha_1 - \alpha_2)$ = -68.0
} 2 meters down

α_1 (80 μA) : 180
α_2 (30-30 μA : 87.5
$(\alpha_1 - \alpha_2)$: -69.5
} 3 meters down

α_1 (80 μA) : 16.5
α_2 (30-30 μA) : 87.5
$(\alpha_1 - \alpha_2)$: -71.0
} 4 meters down

α_1 (80 μA) : 13.5
α_2 (30-30 μA : 87.5
$(\alpha_1 - \alpha_2)$: -74.0
} 5 meters down.

4 8/14/28

4 λ □ cont.

α_1 (50 μA) = 17.0

α_2 (50-30 μA) = 87.5

$(\alpha_1 - \alpha_2) = -70.5$ } 8 meter down

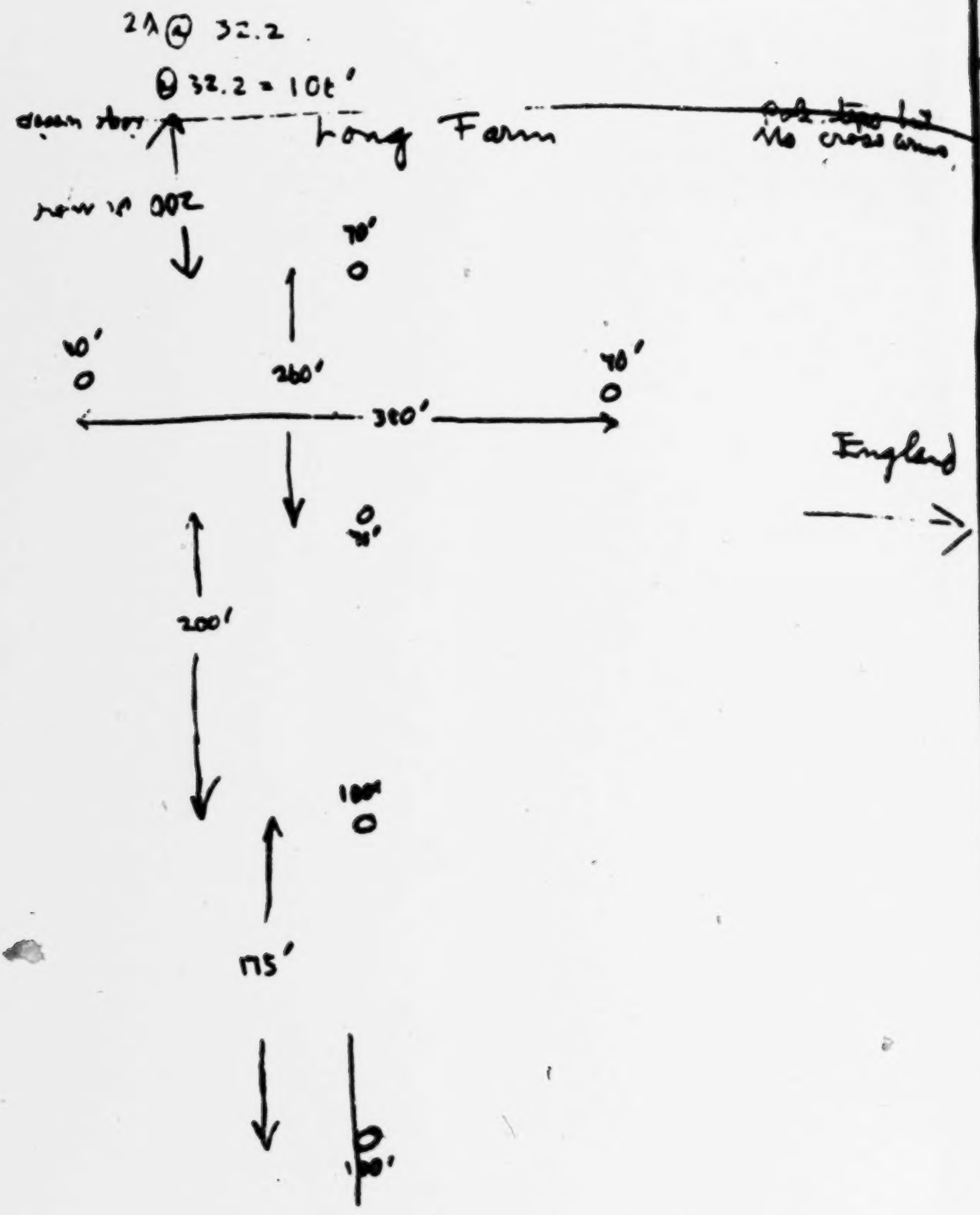
1.4 to 7.

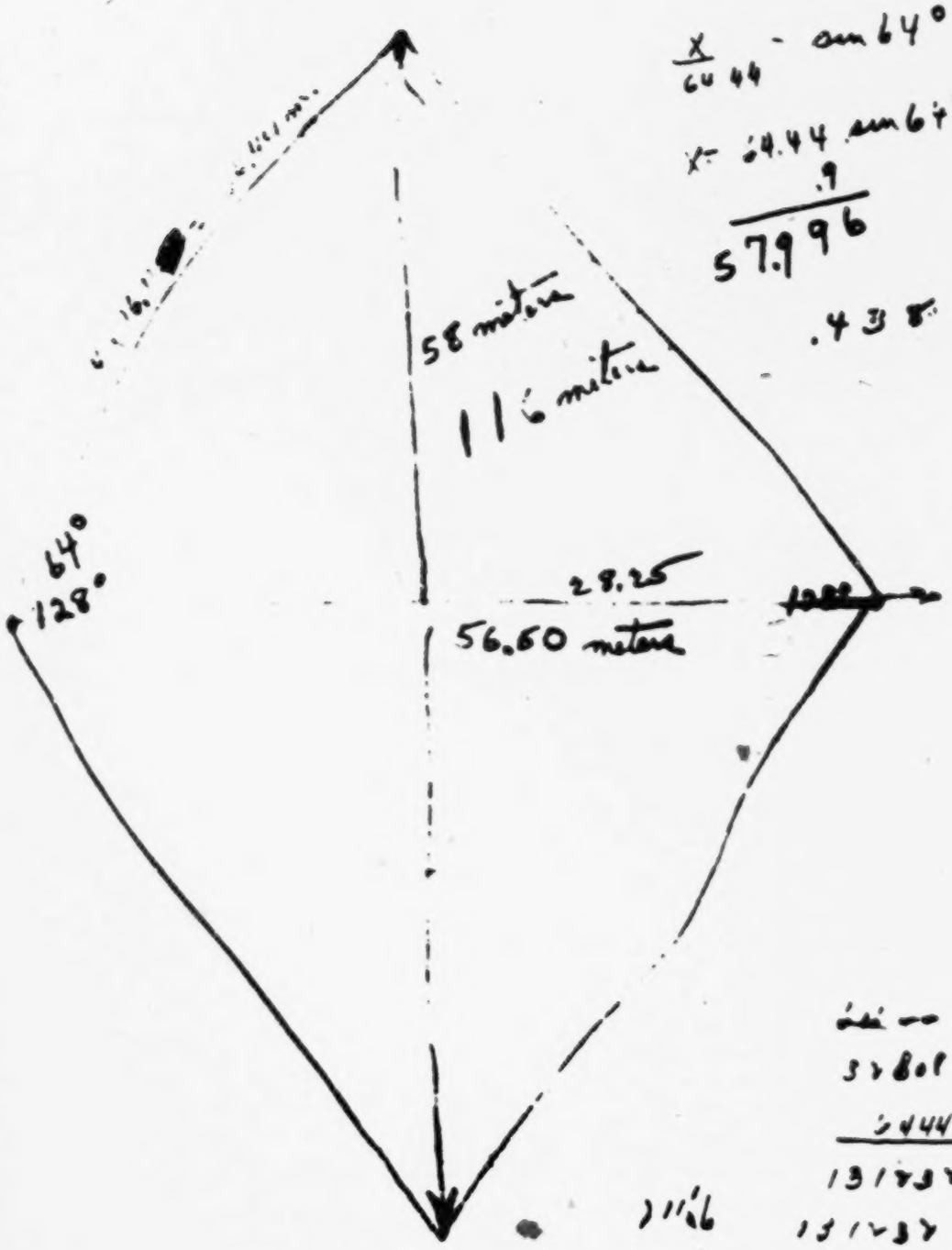
case 1 (vertical) filter sw. closed. Bottom forward
1/16 change - 80 μA - α_1 = 22 α_2 for 29-29 = 89.5
$\alpha_1 - \alpha_2 = -65.5$ TU

λ tilt (toward oscillator) N_A = 12t/ct 80 μa change
α_1 = 25.5 TU α_2 for 30-30 = 89.5 TU
$\alpha_1 - \alpha_2 = -63$ TU

λ tilt (away oscillator)
α_1 = 22.8 TU

2λ (away oscillator)
H from top of pole meters α_1 (80 μa)
0 23 2


2 λ @ 32.2
@ 32.2 = 10t'
stream start
Long Farm
new in 002
70'
40'
260'
40'
300'
England
200'
175'



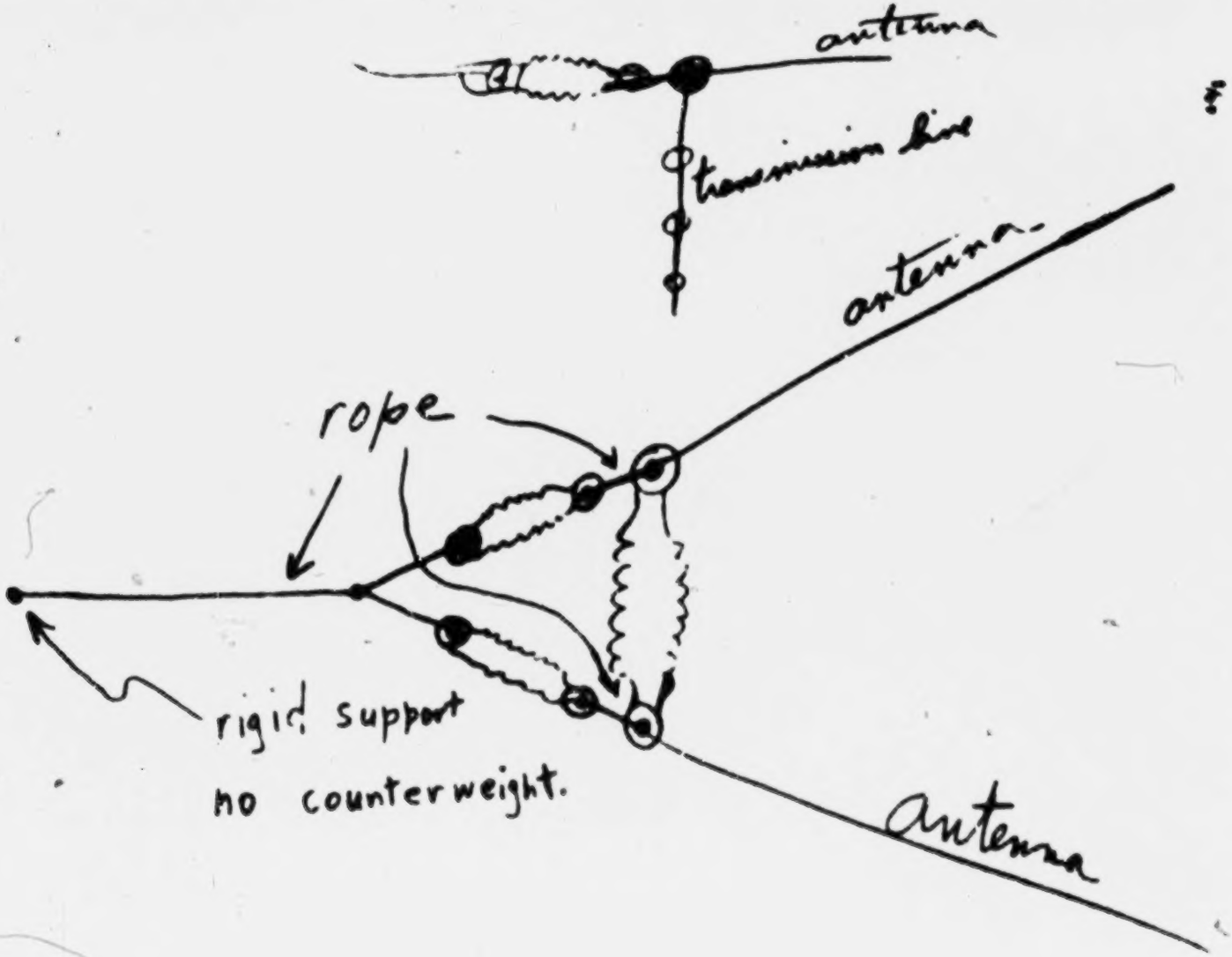
$\frac{x}{60\ 44}$ - am 64°

x = 64.44 am 64°

.9

57.996

.438


antenna
transmission line
antenna
rope
rigid support
no counterweight.
antenna

Apr. 24, 1930

Horizontal Vee - front end open
oscillator at 16.11 metres - approx 825 ft. away.

front → 19.0
back → 11.8
ratio 62

April 29. 1930

Ratio of horizontal to vertical pickup -- front end open, osc. approx 825 ft in front of 16.1 metres, way coupling, etc. → 30.4

Frequency run.

Reading		Osc. adjustment	M.C.	dk	degrees dk
[illegible]	183.2	10			cannot tune antenna
177.2	179.3	15			" " "
172.9	179.8	20			" " "
166.1	170.1	25	19.88	20.2	44 full coupling not [illegible]
163.2	165.0	30			44.5
160.6	164.0	35			45
158.8	158.7	40			44
149.0	152.1	45			42
144.1	149.8	50			40.5
139.5	147.1	55			42
135.6	136.2	60			42.5
129.8	133.9	65			40.5 some subfrequencies from KK=
125.0	128.4	70			41
120.0	125.0	75			39.5 coupling all in
115.2	120.3	80			40
110.4	115.8	85			38
105.6	111.2	90			37.5
100.0	106.9	95			37
96.0	102.4	1011	22.65	12.45	36.5

This page important to Patent Department. Must file on original Rhumbic Antenna E.B.

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Comparative Measurements on GBU. 5/1/30

set No. 14
2 bottom pressed

Time PM	Inches of Rain during 24 hrs ending 7:30 PM		Velocity of wind in 100 ft/sec		Velocity of wind in ft/sec	Temp. of wind in °F	Temp. in °F	Remarks on Log sheet
				mph				
2:45	79.0	82.5	25	17.5	58	65.0	+11.0	
46			26	25	53	62.5	+4.5	
47			24	17	55	65.5	+10.5	
48			22	12.5	57	70	+13	
49			20	6	59	76.5	+17.5	
50			16	13	63	69.5	+6.5	
51			18	8	61	74.5	+12.5	
52			18	8	61	74.5	+12.5	
53			14	7	65	75.5	+10.5	
54			15	7	64	75.5	+11.5	
55			15	10	64	72.5	+8.5	
56			13	6	66	76.5	+10.5	
57			18	5	61	77.5	+16.5	
58			25	11.5	54	70	+16.0	
59			27	12.5	52	65	+13.0	
3:00			35	19	44	68.5	+20.5	Leak 40
3:01			28	22	41	68.5	+9.5	" 42
02			28	22	51	68.5	+3.5	
03			30	23	49	60.5	+11.5	
04			24	22	55	60.5	+5.5	
05			24	12	55	70.5	+15.5	
06			20	12	57	70.5	+11.5	
07			16	2.5	63	75.0	+12.0	
08			20	11	59	70.5	+11.5	
09			22	12	57	70.5	+13.5	
10			26	18	53	64.5	+11.5	
11			24	19	55	60.5	+3.5	
12			27	20	50	62.5	+12.5	
13			25	20	54	62.5	+8.5	
14			29	17	57	65.5	+13.5	
15			26	19	53	63.5	+11.5	
16			27	20	52	62.5	+10.5	
17			17	17	54	65.5	+13.5	
18			29	25	50	53.5	+3.5	
19			26	21	53	61.5	+8.5	
20			25	19	54	65.5	+11.5	
21			29	17	51	65.5	+14.5	
22			26	22	53	60.5	+3.5	
23			25	21	54	61.5	+7.5	
24			22	15	57	67.5	+10.5	
25	79.0	82.5	30	14	59	68.5	+9.5	end.

April Work Report. Wks

During the month of April work was divided approximately as follows:-

Permanent equipment at Holmdel	10%
Supervision of pole setting by N.J. Bell Co.	20%
Horizontal "Vee" antenna	70%

The oscillograph and its associated equipment was completed during April. The batteries were wired to the new charging board, and the new battery chargers installed. The monitoring and switching relay rack in our office was also completed. The [redacted] new poles for the Holmdel site [redacted] by the New Jersey Bell Telephone Company. Eight one hundred foot poles and ten seventy foot poles were erected. This work was completed on April tenth.

Work was then started on the erection and testing of a four wavelength horizontal vee antenna. This was erected on four seventy foot poles located on the same broadside line [redacted] as the other antennas on the Roberts Farm.

A new [redacted] set house was a

Page Tightly Bound

(2)

located and measuring set #14 is being used for measurements on the antenna. A number of circuits for connecting the transmission line to the set were tried and a suitably balanced one is now being used. In this circuit a tuned balancing transformer is used in a separate shielded box, and the output from this is tapped for proper impedance match into the antenna coil of the set. (ratio low to next 30 db.)

Studies of front end termination were then made. When a pure resistance is used approximately seven hundred ohms gives best front to back ratio (approx. 15 db.) and when a resistance of approximately nine hundred ohms and in series with an inductance is used front-back ratios of more than 45 can be obtained.

A frequency run with ~~with~~ was made with the front end open, (...ected)

Readings were then taken of the actual level of CBV in db. below one volt each minute over a forty minute period, and then compared with the recorded values

Page Tightly Bound

(2)

on the half wave vertical antenna. This shows that the horizontal rec antenna gave an effective improvement of about eleven db. above the half wave vertical during this observed period. More careful observations of the improvement can be made when the receiver is in operation on the horizontal rec

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The month of May was spent on work in connection with the development of the horizontal sea antenna. About seventy five percent was spent in work on the antenna and its termination, and twenty five percent on adapting set #4 for continuous recording.

Further work was done on the termination of the antenna for good front to back ratio. Near carbon resistors of a larger and more substantial type than pencil leads were obtained and are being used. Frequency runs have been taken for terminations consisting of a pure resistance alone and a resistance and resistance together. Good front to back ratios can be obtained over a comparatively large frequency range.

Work has been done on the equipment in the termination box between the lead in and the pipe line. An endeavor has been made to get a flat frequency characteristic over a large range without retuning the condensers in this equipment. To do this tight coupling of the two coils has been used. A substantially flat characteristic

in lack of travel from Chester to Boston, Massachusetts.

I sent them were spent with Mr. [illegible] in obtaining attenuation curves using the ground for both vertically and horizontally polarized waves. The result of this work will be reported by him.

A test of the horizontal antenna shows that the response to vertically polarized waves coming in from the ninety degree position is one greater than the response to the same type of radiation in front of the antenna.

In corporation with Mr. Lowry work is progressing in remodeling sets #14 and 17 for continuous recording work. The new attenuator panels are now completed and the recorders have arrived.

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DEFENDANT'S EXHIBIT UU

NUMBER (Series of 1925)

[illegible] 7

DIV. 51

1927523

PATENT NO.

1929

DATED SEP 10 1935

(EX'R'S BOOK) 133 11 5

Name NILS E. LINDENBLAD

Assd to Radio Corporation of America, a corp of Delaware

of PORT JEFFERSON, LONG ISLAND

State of NEW YORK

Invention ANTENNAS FOR RADIO COMMUNICATION

ORIGINAL	RENEWED
APPLICATION FILED COMPLETE DEC 24, 1928	
Petition, Specification, Oath, First Fee ($), 1 sheets Drawings. DEC 24, 19 8	
Examined and passed for issue Feb. 21, 1933 Clyde Bacon Exr. Div. 51	Reexam'd and passed for issue ..., 192 ... Exr. Div.
Notice of Allowance Feb 24, 1933 By Commissioner	Notice of Allowance ..., 192 By Commissioner
Final Fee Aug 23, 1933	Final Fee ..., 192

Attorney IRA D. ADAMS C/O RADIO CORP OF AMERICA ~~65 BROADWAY~~ NEW YORK N

Associate Attorney H. B. Sawyer 30 Rockefeller Plaza 570 Lexington Ave

No. of Claims Allowed 23 (23) Print Claim 3 in O. G. Class 250 - 33

Title as Allowed Antennas for Radio Communication

1929

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C.C.U.S.PAT.OFFICE

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PETITION

JAN 4 - 1929

TO THE HONORABLE COMMISSIONER OF PATENTS:

Your petitioner, NILS E. LINDENBLAD

a citizen of the United States, residing at Port Jefferson, Long Island,

in the County of Suffolk, State of New York

whose Post Office address is Port Jefferson, Long Island, New York.

prays that Letters Patent may be granted him for the improvement in

ANTENNAS FOR RADIO COMMUNICATION

set forth in the accompanying specification.

And he further prays that you will recognize Mr. J. Adams, care of Radio Corporation of America, [illegible] New York, as his attorney, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent Office connected therewith.

[signature]

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, NILS E. LINDENBLAD, a citizen of the United States and resident of Port Jefferson, Long Island, New York, have invented certain new and useful improvements in

ANTENNAS FOR RADIO COMMUNICATION

of which the following is a specification accompanied by drawings:

This invention relates to antennas for radio communication.

Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency, and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment. It is an object of my invention to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency, and a further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices.

My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and which gradually diverge to a much wider spacing at their other ends. In effect, therefore, the antenna consists merely of a gradually diverging extension of the conductors of the transmission line, and, in one aspect, the invention resides in the discovery that radiation may be obtained from a transmission line by gradually increasing the spacing between the wires of the line.

The desired radiation takes place in the direction of the axis of the pair of conductors, and is caused by the expansion of the current or the travelling wave of energy in the conductors. Reflection will cause a standing wave, instead of a travelling wave, and result in radiation sideways from the antenna. Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet. However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention. It is not feasible, in the case of a transmitting antenna, to avoid standing waves by closing the end of the antenna with a surge resistance, because of the excessive losses which would take place therein.

To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation, and on the other hand, to keep the same angle of divergence necessitates so wide a spacing as to make the antenna structurally inconvenient. To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively.

I have also found that a pair of converging conductors, like a pair of diverging conductors will radiate energy, but this radiation is in opposite phase. The antenna may therefore comprise a plurality of pairs of conductors which successively diverge and converge, with means coupling the antennas which reverse the phase of the energy fed thereto.

While the terminology employed in the foregoing description may apply more particularly to a transmitting antenna the structure set forth is equally useful as a receiving antenna.

The invention is further described in the following specification, which is accompanied by a drawing in which

Figure 1 represents one form of my invention;

Figure 2 is a modification employing straight conductors;

Figure 3 shows the use of a plurality of diverging and converging antennas;

Figure 4 is a section of figure 3 taken on the line 4-4; and

Figure 5 is a modification of figure 3 showing an alternative form of phase reversing coupling means between the successive antennas.

Referring to figure 2, it will be seen that the antenna consists of a pair of conductors 2, 4, which are connected to a transmission line 6 at points 8 and 10, which are spaced at the spacing of the transmission line. From the points 8 and 10 the conductors 2 and 4 gradually diverge to a much wider spacing at the ends 12 and 14. The extension of the conductors may be curved, as shown, and one form which is quite successful in operation is an expansion according to an exponential law.

However, in actual practice I find that the refinement of an exponential curve is not essential, and that the conductors 2 and 4 may be straight conductors strung between the points 8 and 12, and the points 10 and 14, under direct tension, and without the use of intermediate shaping or guy wires, and such an arrangement has been indicated in figure 3.

No impedance matching device is necessary with this antenna, so that in actual practice the antenna is exceedingly simple to erect, it being necessary merely to provide a pair of supporting points 12 and 14 at a desired distance from the termination of the transmission line, and then to continue the conductors of the transmission line directly to the spaced points 12 and 14.

Whatever amount of energy has not been radiated when the travelling wave reaches the end of the antenna is reflected, and thus causes a partial standing wave, which will extend back along the transmission line 6. If the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may prove desirable to employ an impedance matching device between the transmission line and the antenna, as is indicated by the impedance matching unit 16, shown in figure 2.

If, instead, the antenna is made to radiate more energy, the standing wave will incidentally be reduced, and the impedance matching device may be dispensed with. To merely make the antenna much longer, while keeping the same spacing at its open end, does not help, because such a procedure merely slows up the rate of spread of the energy, and does not increase the quantity of energy radiated. On the other hand it ordinarily is not structurally possible to make the antenna considerably longer while maintaining the same angle of divergence of the conductors, owing to the great spacing which would be needed at the open end of the antenna. The same result may be accomplished without these disadvantages by using a plurality of antenna sections arranged end to end. Since a converging antenna is similar in operation to a diverging antenna, except for a reversal in phase, it becomes especially convenient to use a plurality of antenna sections which are successively diverging and converging, and such antennas have been indicated in figures 3 and 5.

Referring to figure 3 it will be seen that a transmitter 20 is coupled to a diverging antenna 22 by a transmission line 4. The diverging antenna 22 is followed by a converging antenna 24, which is coupled to the diverging antenna 22 by a pair of conductors 26 and 28. The spacing between these conductors is kept constant, so that practically no radiation takes place therefrom, but at the same time the conductors are electrically crossed in order to reverse the phase of the energy being fed from antenna 22 to antenna 24. For this purpose each of the conductors is supported, at least approximately, in the form of a helix, a feature which is more clearly indicated in the section taken on the line 4-4, and constituting figure 4. The pitch of the helices should be sufficiently great that the physical distance in space between the antennas 22 and 24 is substantially equal to the distance along the conductors 26 and 28, so that the phase displacement of the wave travelling in space will coincide with that of the energy wave travelling on the conductors 26 and 28. The converging antenna 24 is followed by a diverging antenna 30, and the adjacent ends of the antennas 24 and 30 are coupled by phase reversing coupling conductors 32 and 34.

A modification of the arrangement shown in figure 3 is indicated in figure 5, in which a transmitter 20 is coupled by a transmission line 24 to a diverging antenna 22, followed by a converging antenna 24, which in turn is followed by a diverging antenna 30, much as in figure 3. However, in this case the antennas 22 and 24 are coupled by conductors 40 and 42, which are a half wave in length, in order to reverse the phase of the energy flowing therethrough, and which are bent back upon themselves so as to be substantially nonradiating. The connection between the antennas 24 and 30 is made simply by crossing the conductors, as shown, the conductors being separated slightly at the crossing point by an insulator in order to prevent a short circuit between the conductors. In the arrangements shown in figures 3 and 5 any desired number of antenna sections may be employed.

The plane of polarization of the radiated energy coincides with the plane of the conductors, so that if the conductors are positioned in a horizontal plane the energy is radiated with horizontal polarization, and if the conductors are positioned in a vertical plane the energy is radiated with vertical polarization.

With the conductors in a horizontal plane a standing wave tends to cause side radiation. By locating the conductors in a vertical plane the directivity in azimuth may be maintained regardless of the presence of standing waves, but even in such case it is desirable to prevent waste of the energy radiated thereby, and it is therefore desirable to make the length of the conductors or the number of antenna sections sufficiently great, in accordance with the foregoing instruction, to reduce the standing wave.

Figure 4

It will be understood by those skilled in the art that if improved directivity is desired a plurality of these antennas may be employed abreast or in broadside, that is to say, collaterally spaced apart in parallel formation along a line at right angles to the desired direction of communication.

Page Tightly Bound

Since the preferred radiation is from the travelling wave, and is due to the expansion of the lines of force between the current charges travelling along the conductors, the divergence should preferably be fairly gradual, and the spacing at the open end, while variable over a great range, should be in the neighborhood of a fifth of the length, and the length of each antenna section should be of the order of magnitude of five to ten waves long.

The antenna is equally suitable both for transmission and reception, the energy in the latter case being collected and converged into the transmission line without the necessity of an impedance matching device.

I CLAIM:

1. The method of radiating or collecting high frequency electrical energy which includes directing the energy in a plurality of gradually diverging paths.

2. The method of radiating or collecting high frequency electrical energy which includes directing the energy in a plurality of gradually converging paths.

3. The method of radiating or collecting high frequency electrical energy which includes directing the energy successively in a plurality of gradually diverging and converging paths.

4. The method of radiating or collecting high frequency electrical energy which includes directing the energy in a pair of gradually diverging paths, and preventing reflection of the energy travelling in these paths.

5. The method of radiating or collecting high frequency electrical energy which includes directing the energy successively in a pair of gradually diverging and converging paths until reflected energy is reduced to a desired minimum.

6. An antenna comprising a gradually diverging pair of conductors extending in the direction of desired communication.

7. An antenna comprising a gradually diverging pair of conductors extending in the direction of desired communication.

8. An antenna comprising a gradually converging pair of conductors extending in the direction of desired communication.

Page Tightly Bound

9. An antenna comprising a pair of conductors extending in the direction of desired communication, the effective portions of which gradually diverge and converge successively.

10. A transmitting antenna comprising a pair of conductors extending in the direction of desired transmission, the radiating portions of which gradually diverge and converge successively.

11. In combination, a transmission line and an antenna connected thereto comprising gradually diverging extension of the conductors of the transmission line at their remote open ends.

12. In combination, a transmission line and an antenna comprising an open ended pair of conductors which at one end are spaced at the spacing of the transmission line and are coupled thereto, and which gradually diverge to a much wider spacing at their open ends.

13. In combination, a transmission line, and an antenna connected thereto comprising a pair of open ended conductors of the order of magnitude of a number of wave lengths long which are widely spaced at the ends remote from the transmission line, and spaced at the spacing of the transmission line at their junction therewith.

16. An antenna comprising a plurality of pairs of gradually diverging conductors extending in the direction of desired transmission.

(over)

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12. In combination, a transmission line, an antenna connected thereto comprising a pair of conductors a number of wave lengths long which are spaced at the spacing of the transmission line at their junction therewith, and which gradually diverge to a much wider spacing at their remote ends, a second antenna comprising a pair of conductors a number of wave lengths long arranged in extension of the first antenna, and widely spaced at their near ends and closely spaced at their remote ends, another diverging antenna arranged in extension of the converging antenna, and phase reversing means for coupling said antennas together.

Amend C 2 at 13-15
Amend E dutto 39
add By

Witness
Lin C Lumbard

BSF:AU

AFFIDAVIT

STATE OF ..... NEW YORK .....
COUNTY OF ..... SUFFOLK ..... ss.:

..... WILLIS R. LINDENBLAD ..... the above named petitioner, being duly sworn, deposes and says that he is a ..... citizen of the United States ..... and resident of ..... Port Jefferson, L.I. in the County of ..... Suffolk ....., State of ..... New York. and that he verily believes himself to be the original, first, and sole inventor of the improvements in ..... ANTENNAS FOR RADIO COMMUNICATION .....

..... described and claimed in the annexed specifications; that he does not know and does not believe that the same were ever known or used before his invention or discovery thereof; or patented or described in any printed publication in any country before his invention or discovery thereof or more than two years prior to this application; or patented in any country foreign to the United States on an application filed by himself or his legal representatives or assigns more than twelve months prior to this application; or in public use or on sale in the United States for more than two years prior to this application; and that no application for patent on said improvements has been filed by him or his representatives or assigns in any country foreign to the United States.

.....

.....

.....

Willis R. Lindenblad

Sworn to and subscribed before me this ..... Seventeenth ..... day of ..... December ....., 1928.

W. A. Braff

Notary Public.

Fig. 1
Fig. 2
Fig. 3
Fig. 4
Fig. 5

#2

MAIN DIVISION
APR 26 29
U.S. PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF N. E. LINDENBLAD :
FOR ANTENNAS FOR RADIO COMMUNICATION :
SERIAL NO. 228,147 FILED: Dec. 24, 1927
DIVISION 51 ROOM NO. 240 Ax. :
LAST OFFICE ACTION: :

New York, N.Y., March 7, 1929.

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

Sir:

APPOINTMENT OF ASSOCIATE ATTORNEY.

I hereby appoint, H. G. GROVER, (Register Number 3988), whose Post Office address is C/o Radio Corporation of America, 233 Broadway, New York, New York, as associate attorney to prosecute the above entitled application, to make alterations and amendments therein, to receive the patent and to transact all business in the Patent Office connected therewith, and I further direct that all correspondence concerning the aforesaid application be mailed to the said associate attorney appointed hereby.

Leigh Adams
Attorney of Record.

Div. 51 Room 840-Annex Paper No. 3

Address only The Commissioner of Patents, Washington, D. C., and not any official by name. RPM:MCG

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON September 25, 1929.

SEP 25 1929

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
Commissioner of Patents.

H. O. Grover,
C/o Radio Corp. of America,
233 Broadway,
New York, N. Y.

Applicant: H. E. Lindenblad

Ser. No. 328,147
Filed Dec. 24, 1928
For Antennae for Radio Communication.

This application has been examined.

Record is made of:

Arton	794,284	July 11, 1905	250-11
Garcia	795,762	July 25, 1905	250-11
Athearn	918,856	Apr. 13, 1909	250-33
Fessenden	1,147,010	Jul. 20, 1915	250-33

"The Wireless Age", September, 1921, pages 36 and 37, published by The Wireless Press, Inc., 250-33.

In the drawing, the phase reverser should be indicated as such so as to illustrate the combination.

Claims 1, 6, 7, 12, 13 and 14 are rejected on any one of the references, Wireless Age, Arton or Garcia.

Claims 2 and 8 are rejected on Fessenden who shows converging antenna.

Claim 3 is rejected on Athearn who shows antenna arranged with the conductors in successively diverging and converging paths.

Claims 4 and 5 are rejected like claim 3. The only distinction over the reference is in functional limitations. Furthermore, claim 4 is inaccurate in claiming preventing reflection of energy. Apparently all that applicant does is reduce the reflection of energy.

Claims 9, 10 and 11 are rejected on Athearn like claim 3.

Claim 15 appears to be allowable.

O. O. Buck

Examiner

R.M.

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IN THE UNITED STATES PATENT OFFICE

JAN 30 30

APPLICATION OF NILS E. LINDENBLAD :
FOR ANTENNAE FOR RADIO COMMUNICATION :
SERIAL NO. 328147 FILED DEC. 24, 1928 :
DIVISION 51 ROOM 240-ANNEX :
LAST OFFICE ACTION: SEPTEMBER 25, 1929 :

New York, N. Y. January 29, 1930.

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

SIR:

In response to the Office Action of September 25, 1929, kindly amend as follows:

Claim 1, line 1, before "radiating" insert directively.

Line 2, cancel "the".

Line 2, after "energy" insert of opposite polarity.

Last line, before the period insert diverging and extending longitudinally in the desired direction of radiant action.

Claim 2, line 2, cancel "the".

Line 2, after "energy" insert of opposite polarity.

Line 3, before the period insert diverging and extending longitudinally in the desired direction of radiant action.

Claim 3, line 2, cancel "the".

Line 2, after "energy" insert of opposite polarity.

Last line, before the period, insert and phase reversing the energy as it is directed from one path into another.

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Claim 6, line 2, before the period insert diverging and extending longitudinally only in a desired direction of radiant action.

Claim 7, line 2, after "conductors" insert diverging and.

Line 2, after "extending" insert longitudinally only.

Claim 8, line 2, after "conductors" insert excited in phase opposition, converging and.

Line 2, after "extending" insert longitudinally only.

Claim 9, line 1, after "extending" insert longitudinally.

Claim 10, line 2, after "extending" insert longitudinally.

Last line, before the period, insert in the direction of desired transmission.

Claim 11, line 2, after "thereto" insert extending longitudinally in the direction of transmission.

Claim 12, line 1, after "antenna" insert extending longitudinally in the direction of desired radiant action.

Claim 13, line 1, after "antenna" insert extending longitudinally in the direction of desired radiant action.

Line 4, before the comma, and after "line" insert and energized with energy of opposite polarity.

Claim 14, line 2, after "extending" insert longitudinally.

Last line, before the period, insert and energized in phase opposition.

REMARKS:

The Official Draftsman has been requested to amend the drawing as suggested.

Favorable reconsideration of claims 1, 6, 7, 12, 13 and 14 over the art of record is thought to be in order and is, therefore, respectfully requested.

Turning to claim 1, no one of the references of record discloses the transmission of energy of opposite polarity in a

plurality of diverging paths diverging and extending longitudinally in the desired direction of radiant action. In addition, no one of the references teaches phase reversal of energy as it travels from the converging path to the diverging path or vice versa. And, similar to claim 1, no one of the references teaches as called for by claims 13 and 14 conductors diverging and extending longitudinally in the direction of desired transmission, which conductors are energized in phase opposition.

Artom discloses antennae of two sections which extend longitudinally downwardly and not in the direction of desired transmission. Similarly, Athearn fails to show conductors extending longitudinally or diverging in the desired direction of radiant action. Fessenden fails to disclose diverging or converging conductors excited in phase opposition. The latter failure is also present in the Garcia patent and in the Wireless Age article cited against this case.

Turning to claims 6 and 7 the Examiner's attention is respectfully directed to the feature therein to the effect that the conductors diverge and extend longitudinally only in a single direction, that being the direction of desired radiant action. The Wireless Age discloses at best, a non-directional antenna; for, it is stated therein that most of the radiation occurs from the vertical connection to the antenna which, as is well known in the art, radiates uniformly about its axis. Garcia discloses conductors which extend in more than the desired direction of transmission as does also Fessenden. As the Athearn antenna extends vertically it, of course, does not extend in the desired direction of radiant action. Artom, of course, does not extend longitudinally in the direction of radiant action but extends longitudinally downwardly.

As Athearn fails to disclose phase reversal of energy as it travels from a diverging path to a converging path it, of course, is inapplicable in the rejection of claim 8 which now calls for such phase reversal.

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The prevention of reflection of energy in antennae of applicant's type is a new and useful teaching in the art and, therefore, is entitled indubitably to patent protection. Applicant discloses in his specification that reflection is detrimental to proper radiant action and that it may be effectually prevented in two ways; first, by terminating his antenna with a suitable resistance which, however, applicant points out, is objectionable because of the waste of energy; and secondly, and more important, applicant teaches that by making his antenna sufficiently long reflection is prevented by virtue of the fact that all of the energy is radiated. However, applicant shows that to make an antenna of one section sufficiently large to radiate all of the energy would not be practically feasible. He then teaches the art that by making it a plurality of sections successively diverging and converging, the antenna may be retained within workable physical limits without the presence of detrimental reflection phenomena. None of the art teaches the problem and still less does any of it solve the problem. Accordingly, claims 4 and 8 which state reflection prevention as a positive step are unequivocably patentable over the art of record and should upon the next Office Action be allowed.

Remarks similar to those given hereinbefore apply with equal cogency to claims 9, 10 and 11 which call for diverging and converging sections for an antenna extending <u>longitudinally</u> in the desired direction of radiant action. Moreover these claims call for the <u>gradual</u> divefgence or convergence of the sections which, it is submitted, is not taught by Athearn, the reference relied upon in rejecting these claims. Athearn shows sharp divergence from his transmission lines 6-6 which, in short wave work for which applicant's antenna system is especially adapted, would prove highly detrimental and prevent proper action.

For the foregoing reasons allowance of the case in its present form is thought to be in order and is, therefore, respectfully requested.

Respectfully submitted,

ERIK E. LINDENBLAD

BY W. S. Bowen
Attorney

HT:AJ

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Radio
MAIL DIVISION
JAN 30 30
PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF NILS E. LINDENBLAD :
FOR ANTENNAE FOR RADIO COMMUNICATION :
SERIAL NO. 388,147 FILED DEC. 24, 1929 :
DIVISION 21 ROOM 240-ANNEX :
LAST OFFICE ACTION: SEPTEMBER 25, 1929 :

C print

New York, N. Y. January 28, 1930.

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

ACCOUNT
JAN 31 1930

ATT: OFFICIAL DRAFTSMAN

SIR:

The Official Draftsman is requested to add the legend "phase reverser" on the drawing as it appears in ink on the accompanying print. It is requested that, when the additions have been made, the photostat be returned to applicant; and, that the cost of making the additions be charged to the account of Radio Corporation of America.

Respectfully submitted,

Approved
2/15/30

RECEIVED IN O'V C
FEB 11 1930

NILS E. LINDENBLAD

BY _____
Attorney

NT:AU

CORRECTION CHARGED
FEB 19 1930
50 ¢
POINT CHARGE
FINANCIAL

CORRECTED
FEB 24 1930
DRAFTING DIV.

51 Room 240-Annex Paper No. 5

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

RFL:LCG November 8, 1930

Send to [illegible] communication from the EXAMINER.

Thomas E. Robertson

Applicant E.F.Lindenblad

H. G. Grover,
C/o Radio Corp. of America,
233 Broadway,
New York, N. Y.

Ser No 328,147
Filed Dec. 24, 1928
For Antennas for Radio Communication

Responsive to applicant's communications of January 30, 1930.

Additional record is made of:

Espenschied	1,353,735	Sept. 21, 1920	250-33
Stanley	1,738,489	Dec. 3, 1929	250-33
British Patent	323,742 (1 sht.)	Oct. 30, 1924	250-33

The operation of applicant's device to give directional transmission is questioned. It is not seen how two lines as shown by applicant will give the desired effect. Applicant should give a satisfactory explanation, or submit proper proof of the operativeness of the device to give the directional effects ascribed to it.

The claims are accordingly all rejected as being drawn to a device inoperative to perform the functions desired.

Claims 2 and 3 as amended are further rejected as misdescriptive since they recite "gradually converging paths diverging". Apparently the paths should converge instead of diverge.

Claim 4 is further rejected as unpatentable over Athearn, since it is not new as shown by Espenschied to prevent reflection in an antenna.

Claim 4 is further rejected as misdescriptive since it appears that applicant merely reduces the reflection of

energy and does not prevent reflection.

Claim 5 is rejected as unpatentable over the British patent, supra, since no method different from that used in the British patent is included in the claim. Since the wires of this reference successively converge and diverge, it follows that energy directed along this antenna follows a converging and diverging path. Applicant's method merely adds the statement about reflection being reduced by this process but gives no additional steps over those made in using the British antenna.

Claims 6, 7 and 9 are rejected as unpatentable over Garcia, of record, or Stanley, supra. Both these references show an antenna composed of conductors extending in the direction of transmission. The limitation, "diverging and extending only in the direction of desired communication" is indefinite and does not point out the invention. The direction of "desired communication" may be in all directions.

Claims 10 and 11 are rejected as unpatentable over the British patent, supra, since the limitation as to the direction of the antenna with respect to the transmission line is considered immaterial.

Claims 1, 3, 12, 13, 14 and 15 appear to distinguish over the references and may be considered allowable upon satisfactory showing of the operativeness of the device.

R M

W. W. Brown

Examiner

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#6

MAIL DIVISION
APR 22 1931
U.S. PATENT OFFICE

UNITED STATES PATENT OFFICE

APPLICATION OF: NILS E. LINDENBLAD

FOR: ANTENNAS FOR RADIO COMMUNICATION

SERIAL NO. 328,147 FILED: Dec. 24, 1928

DIVISION: 51 ROOM: 240-ANNEX

April 22, 1931.
New York, N. Y.

The Commissioner of Patents

Washington. D. C.

Sir:

On and after April 24, 1931, please address all communications intended for the attorney of record of the above entitled case to

Harry G. Grover
c/o Radio Corporation of America
570 Lexington Avenue
New York City, N. Y.

Respectfully,

NILS E. LINDENBLAD

by H. G. Grover
Attorney

MAIL DIVISION
MAY 5 31
U.S. PATENT OFFICE

PAPER NO. 7
AMENDMENT B

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF: NILS E. LINDENBLAD :
FOR: ANTENNAE FOR RADIO COMMUNICATION :
SERIAL NO: 322,147 FILED: DEC. 2, 1928 :
DIVISION: 51 ROOM: 240-ANNEX :
LAST OFFICE ACTION: NOVEMBER 8, 1930 :

PATENT OFFICE
MAY 6 - 1931

New York, N. Y. April 28, 1931.

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

SIR:

In response to the Office Action of November 8, 1930, kindly amend this case as follows:

Cancel claim 8 and rewrite it as follows:

20 The method of unidirectionally radiating or collecting high frequency electrical energy which includes directing energy of opposite polarity in a plurality of gradually converging paths converging and extending longitudinally in the desired direction of radiant action.

Cancel claim 4.

Cancel claim 5.

Claims 6, 7, 8 and 9, change "An" to a unidirectional.

Claim 6, line 2, after "conductors" insert excited in phase opposition.

Claim 7, line 2, after "conductors" insert excited in phase opposition.

Claim 9, line 1, after "conductors" insert excited in phase opposition.

Claim 10, line 1, before "transmitting" insert unidirectional

Line 2, after "conductors" insert excited in phase opposition.

Yours.

Claim 11, line 1, before "transmission" insert two conductor.

Line 1, after "line" and before the comma insert excited in phase opposition.

Claim 12, line 1, before "transmission" insert two conductor.

Line 1, after "line" and before the comma insert excited in phase opposition.

Claim 14, line 1, change "An" to a unidirectional.

REMARKS:

Applicant is surprised at the Examiner's rejection of this case on the ground of inoperatability. As proof of the operativeness of his present invention applicant submits herewith radiation curves derived from an antenna such as described in his present patent application. If the Examiner desires further proof of the operativeness of applicant's present invention, a mathematical treatment of the operation of his improved directional antenna arrangement will be given. Consequently, it seems that the rejection of the claims as being drawn to an inoperative device must be withdrawn.

Claim 2 has been rewritten so as to avoid the formal objection thereto. Applicant, however, fails to find any objection such as pointed out by the Examiner in connection with claim 8 and accordingly this claim has been allowed to stand as originally presented and amended heretofore.

Inasmuch as applicant feels that the subject matter of claims 4 and 5 is amply covered by the other claims retained in applicant's application, claims 4 and 5 have been cancelled. This cancellation, therefore, is not to be considered at all prejudicial to applicant who does not feel that the art of record teaches the subject matter of these cancelled claims.

It is respectfully submitted that claims 6 to 9 inclusive patentably define over Garcia of record and Stanley last cited by the Examiner. Neither of these references teach, as required by the claims, a unidirectional antenna comprising a pair

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of diverging or converging pairs of conductors excited in phase opposition. The fact that these claims have been restricted to a unidirectional antenna, removes the objection that the desired direction of communication may be in all directions. Applicant has carefully considered the Garcia and Stanley patents of record already referred to, but, as already indicated, he fails to find therein any suggestion to the effect that the conductors extend in the desired direction of communication or, in other words, the single direction in which the antenna is to operate; and, moreover, applicant fails to find therein the fact that diverging or converging conductors are excited in phase opposition as required by the claims. Consequently, these claims upon reconsideration should be allowed.

Similar remarks are applicable in favor of claims 10 and 11 over British patent 223,748 which fails, among other things, to teach a unidirectional antennaas required by these claims and moreover it fails to teach the excitation of diverging or converging conductors in phase opposition as called for by claims 10 and 11.

In view of the proof of the operability of applicant's unidirectional antenna system presented herewith in the form of radiation patterns made in the field from an antenna built in accordance with applicant's present invention, claims 1, 3, 12, 13, 14 and 15 should be allowed since no objection other than than the requirement as to proof of operativeness was made against them.

Respectfully,

NILS E. LINDENBLAD

By _____
Attorney

NT:AU

1201

Div. 61 Room 940-ARRCX Paper No. 8

Address only [illegible] Commissioner of Patents, Washington, D. C.

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

All communications regarding this application should give the serial number, date of filing, and name of the applicant

RPH:AK December 14, 1931

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
Commissioner of Patents.

Applicant: H. E. Linderblad

H. G. Grover
c/o Radio Corp. of America
570 Lexington Ave.
New York, N. Y.

Ser. No. 588,147
Filed Dec. 24, 1926
For Antennas for Radio Communication

MAILED
DEC 14 1931

Responsive to amendment of May 5, 1931.

The claims as amended are considered allowable. However, since the numerous insertions in the same lines of claims 6-12, inclusive, renders them confusing it is required that applicant rewrite these claims before the application may be passed to issue.

Respectfully,

R. D. Baumann

Examiner.

PAPER NO. 9
AMENDMENT C

MAIL DIVISION
MAR - 2 32
U.S. PATENT OFFICE

UNITED STATES PATENT OFFICE

APPLICATION OF: NILS E. LINDENBLAD

FOR: ANTENNAS FOR RADIO COMMUNICATION

SERIAL NO.: 328,147 FILED: DECEMBER 24, 1928

DIVISION: 51 ROOM: 240-ANNEX

LAST OFFICE ACTION: DECEMBER 14, 1931.

PATENT OFFICE
MAR 3 1932

New York, N. Y., March 1, 1932.

COMMISSIONER OF PATENTS,

WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of December 14, 1931, claims 6 to 12 inclusive are being rewritten to avoid [illegible] due to numerous insertions in these claims.

C' 40. A uni-directional antenna comprising a gradually diverging pair of conductors excited in phase opposition, diverging and extending longitudinally only in the desired direction of radiation.

Rej F 50. A uni-directional antenna comprising a gradually diverging pair of conductors excited in phase opposition, diverging and extending longitudinally only in the direction of desired communication.

F 50. A uni-directional antenna comprising a gradually converging pair of conductors excited in phase opposition, converging and extending longitudinally only in the ~~direction of desired communication~~ desired direction of radiation action.

F 60. A uni-directional antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the ~~direction of desired communication~~ desired direction of radiation action, the effective portions of which gradually diverge and converge successively.

7 ~~11.~~ A uni-directional transmitting antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the directions of desired transmission, the radiating portions of which gradually diverge and converge successively in the direction of desired transmission.

8 ~~12.~~ In combination, a two conductor transmission line excited in phase opposition, and an antenna connected thereto extending longitudinally in the direction of transmission, comprising a gradually diverging extension of the conductors of the transmission line at their remote open ends.

9 ~~13.~~ In combination, a two conductor transmission line excited in phase opposition, and an antenna extending longitudinally in the direction of desired radiant action comprising an open ended pair of conductors which at one end are spaced at the spacing of the transmission line and are coupled thereto, and which gradually diverge to a much wider spacing at their open ends.

Please add the following claims:

13 ~~14.~~ A uni-directional antenna comprising a diverging pair of conductors excited in phase opposition, diverging ~~and extending longitudinally~~ only in the desired direction of ~~desired communication~~ radiant actions.

14 ~~15.~~ A uni-directional antenna comprising a converging pair of conductors excited in phase opposition, converging ~~and extending longitudinally~~ only in the desired direction of ~~desired communication~~ radiant action.

15 ~~16.~~ A uni-directional antenna comprising a pair of conductors excited in phase opposition, extending longitudinally in the desired direction of ~~desired communication~~ radiant action, the effective portions of which diverge and converge successively.

REMARKS

The application has been indicated as being ready to pass for issue, which is respectfully requested at an early date. Claims 6 to 12 in this application have been re-written to avoid confusion due to numerous insertions. The language in these claims is identical with that appearing in the claims as originally filed with the insertions added in the several previous amendatory papers.

New claims 13, 14 and 15, respectively, are of scope very similar to allowed claims 7, 8 and 9, differing therefrom only in the omission of the term "gradually". These new claims are, therefore, considered to be clearly allowable.

Respectfully submitted,
NILS E. LINDENBLAD

Attorney.

CMB:EL

31

Paper No. 10

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON March 9, 1932.

EPM:MCG

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
Commissioner of Patents.

Applicant: M. E. Linklenbl.

. G. Grover,
/o Radio Corp. of America,
570 Lexington Avenue,
New York, N. Y.

Ser. No. 328,147
Filed Dec. 24, 1928
For Antennas for Radio Communication.

MAR 9 1932

Responsive to amendment filed March 2, 1932.

Claims 6-12 as rewritten have been entered. Newly added claims numbered 13-15 in the amendment have been renumbered 17-19 in order that the numbers run consecutively.

New claims 17-19 are rejected as being broader than the invention since it is only shown that applicant's device is operative if the antennae are gradually diverging.

New claims 17-19 are further rejected as unpatentable over allowed claims 7, 8 and 9, respectively, since they are substantial duplicates of the allowed claims, as the word "gradually" must be read into them in order to read them on the disclosure.

Claims 1, 3, and 6-16 stand allowed.

RMC

A. D. Bacon
Examiner

MAIL DIVISION
MAR - 8 32

PAPER NO 11
AMENDMENT

UNITED STATES PATENT OFFICE

APPLICATION OF: BILS E. LINDENBLAD
FOR: ANTENNAE FOR RADIO COMMUNICATION
SERIAL NO.: 578,147 FILED: DECEMBER 24, 1928
DIVISION 51 ROOM: 240-ANNEX
LAST OFFICE ACTION: DECEMBER 14, 1931.

New York, N. Y., March 5, 1932.

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

PATENT OFFICE
MAR 9 1932

DEAR SIR:

This supplements applicant's amendatory paper of March 1, 1932.

It is noted that the new claims added in the amendatory paper above referred to have been designated incorrectly by the reference numerals 13, 14 and 15. It is respectfully requested that the reference numerals of these new claims be changed to 17, 18 and 19.

Respectfully submitted,
BILS E. LINDENBLAD
By H. B. Brown
Attorney.

CHB:EC

PAPER NO. 12
AMENDMENT

MAIL DIVISION
AUG-8 32

UNITED STATES PATENT OFFICE

APPLICATION OF: S. B. LINDENBLAD
FOR: ANTENNAS FOR RADIO COMMUNICATION
SERIAL NO.: 626,147 FILED: December 24, 1932
DIVISION: 81 ROOM: 5626
LAST OFFICE ACTION: March 9, 1932.

New York, N. Y., August 4, 1932.

AUG 8 1932

COMMISSIONER OF PATENTS
WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of March 9, 1932, please amend the above-entitled application as follows:

Add the following claims:

16. A highly directional antenna system comprising wires which are long relative to the length of the communication wave excited in phase opposition, which first diverge from the excitation end and then converge successively, whereby radiant action occurs predominantly in a direction substantially through the opposite spices of the wires.

17. A system in accordance with claim 16, characterised in this, that said wires are in a single vertical plane.

18. A highly directional antenna syster comprising a pair of conductors excited in phase opposition, said wires being long relative to the length of the communication wave and extending in the desired direction of ~~desired communication~~ radiation, the effective portions of which diverge and converge successively.

Per K

19. A unidirectional antenna system comprising a pair of conductors which are long relative to the length of the communication wave, said conductors being excited in phase opposition and arranged to first diverge from the excitation end and then converge, whereby radiant action occurs predominantly in a direction through the excitation end of the wires and the opposite apex.

E'court

19a. A highly directional antenna system comprising a pair of conductors angularly disposed with respect to each other, said conductors being long relative to the length of the communication wave and open-ended, and means for exciting the conductors in phase opposition whereby radiant action occurs predominantly along the direction of the axis of the conductor system.

19b. A unidirectional antenna system comprising a diverging pair of conductors, the said conductors being long relative to the length of the communication wave, and means for producing traveling waves thereon whereby radiation is predominantly along the approximate direction of the length of the conductor system.

19c. A system in accordance with claim 19a characterised in this, that said conductors are open-ended and disposed in the same vertical plane.

19d. A directional antenna comprising a diverging pair of conductors which are long relative to the working wave length, and means at adjacent ends of said conductors for energising same in phase opposition, said conductors being arranged to be on the same side of said energising means and to extend away from said energising means whereby radiant action occurs predominantly along the approximate direction of the length of the conductor system.

28. A directional antenna comprising a pair of open-ended, diverging conductors which are long relative to the working wave length, and means at adjacent ends of said conductors for energising same in phase opposition, said conductors being arranged to be on the same side of and to extend away from said energising means whereby radiant action occurs predominantly in a direction making equal angles greater than zero degrees with reference said conductors.

REMARKS.

The Examiner's position with respect to new claims 17 to 19 is not considered to be well taken since he presents two grounds of rejection which are inconsistent with respect to each other. If the new claims 17 to 19 are substantial duplicates of allowed claims 7, 8 and 9 then they define a device which is operative. If claims 17 to 19 define a device which is inoperative then allowed claims 7, 8 and 9 also define inoperative devices and should be rejected since their operability is not a mere matter of degree.

Applicant submits, however, that in his opinion new claims 17 to 19 are of somewhat different scope than allowed claims 7, 8 and 9 and do define an operative device of the type disclosed in Figures 1, 2 and 5 of the drawings. The expression "gradually" now present in the allowed claims, it is thought, might be construed merely to cover a method of using only curved wires of the type indicated by reference characters 24 and 28 in Figure 5, whereas the present invention is intended to apply not only to the use of curved wires, but also to straight linear wires such as shown in Figures 2 and 5 and to wires diverging more abruptly in exponential fashion as shown in Figure 1. Applicant is attempting by adding new claims 17 to 19 to adequately define the present

invention in such manner that the claims are clear, definite and unambiguous, and it is only while the application is still pending in the Patent Office and in the formative state that he is able to present such claims. It is feared that if the present application issues with the term "gradually" recited in the allowed claims that some dishonest competitor in a future law suit may contend that his device does not infringe because the expression "gradually" used in the claims should be construed to cover only curved wires, whereas actually applicant is entitled to cover straight linear wires and wires diverging more abruptly in exponential fashion. For this reason it is submitted that new claims 17 to 19 are not substantial duplicates of the allowed claims, but of somewhat broader scope. Devices in accordance with these claims have actually been used with excellent results, as shown by the radiation curves previously submitted by applicant as proof of the operativeness of his invention. Since these new claims 17 to 19 are patentable over the prior art and clearly within the scope of the present invention it is urged that the Examiner should not be too technical and insist upon the use of a term in the claims which might later be construed to be so vague as to cause him irreparable harm when applicant is clearly entitled as a protection for his invention to the omission of such term in order to present claims which are clear, concise and exact.

New claims 20 to 28 are specific to applicant's highly directional antenna system and are limited to conductors arranged to be energized in phase opposition, a feature lacking in the prior art. Further, claims 21 and 26 call for such a system wherein the wires are located in a single vertical plane, a particularly advantageous arr[illegible]ment which has been used in the

field. New claim 22 is of scope somewhat similar to allowed claim 9. Claim 23 which recites a unidirectional antenna system whereby radiant action occurs in a direction through the excitation end of the wires, a feature of which the art is silent, is more specific in certain respects than allowed claim 9. New claims 24, 26 and 26 are further specific to open-ended conductors, and new claim 25 is limited to the use of traveling waves.

The art of record does not show either highly directional or unidirectional antennae, and still less, antennae conductors energized in phase opposition with respect to each other. Nor do the references show antenna systems wherein the direction of radiation is along the direction of the axis or length of the conductors.

Claims 1, 3 and 6 to 18 stand allowed.

Allowance of new claims 17 to 18, together with new claims 20 to 26, is respectfully requested so that this application may soon pass for issue.

Respectfully submitted,

E. E. LINDENBLAD

By W. E. Brown

Attorney.

GEB:BB

Ex. 81 Room 2428 Paper No. 13

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON December 7, 1932.

Address only The Commissioner of Patents and Trademarks NEM:ESC

Letter find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents.

H. U. Grover,
C/o Radio Corp. of America,
570 Lexington Avenue,
New York, N. Y.

Applicant: H. H. Lindenblad

Ser. No. 588,147
Filed Dec. 24, 1931
For Antennae for Radio Communication

DEC 7 1932

Responsive to amendments filed March 8 and August 8, 1932.

Upon careful review of this application it is found that claim 7 is a duplicate in structure of allowed claim 6. The only difference in these claims is found in the words used to describe the direction of communication. Accordingly, the allowance of claim 7 is withdrawn and this claim is rejected as unpatentable over claim 6.

Claims 17-19 are again rejected as being broader than applicant's invention since as pointed out in the specification, the antennae must gradually converge or diverge in order to properly operate. This is true whether the divergence is in a straight line or according to an exponential curve.

Claims 17-18 are again further rejected as unpatentable over allowed claims 6, 8, and 9 since if modified by the necessary qualification of "gradually" they are identical with these claims in structure.

Claims 20-22, inclusive, are rejected as being broader than the invention since as pointed out in connection with claim 19-19, it is necessary to specify that the emitting conductors "gradually" diverge and converge.

Moreover, claims 20-22 are all duplicates of each other in structure.

P.M.

Examiner

PAPER No. 14
AMENDMENT

MAIL DIVISION
JAN - 5 33

UNITED STATES PATENT OFFICE

APPLICATION OF: H. E. LINDENBLAD
FOR: ANTENNAS FOR RADIO COMMUNICATION
SERIAL NO.: 326,147 FILED: December 24,1928
DIVISION: 51 ROOM: 5628
LAST OFFICE ACTION: December 7, 1932.

PATENT OFFICE
JAN 4 1933
DIV 51 FILED

New York, N. Y., December 30, 1932.

COMMISSIONER OF PATENTS
WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of December 7, 1932. please amend the above-entitled application as follows:

Cancel claim 7.

Claim 8, last two lines, and claim 9, line 8, change "direction of desired communication" to --desired direction of radiant action--.

Claims 17 and 18, line 2, cancel "and";
line 3, cancel "extending longitudinally";
after "the" insert --desired--;
lines 3 and 4, cancel "desired communication" and substitute therefor --radiant action--.

Claim 19, line 3, after "the" first occurrence insert --desired--; cancel "desired communication" and substitute therefor --radiant action--.

Claim 22, line 4, after "the" first occurrence insert --desired--; cancel "desired communication" and substitute therefor --radiant action--.

Cancel claim 25.

AMENDMENT.

In accordance with the interview kindly granted applicant's attorney the above-entitled application is being amended in a manner which, it is believed, will place it in condition for allowance.

Claims 7 and 25 have been cancelled without prejudice merely because it is thought that the subject matter thereof is adequately protected by the remaining claims of this application.

Claims 8, 9, 17, 18, 19 and 22 have been amended in the interest of clarity to recite that the conductors either diverge or converge, depending upon the wording of the respective claims, in the desired direction of radiant action. These amendments, it is thought, render the claims more concise and accurate than before.

Claims 8 and 9, it should be noted, are allowed. The amendments to these claims, it is thought, do not render them unpatentable. It is requested that these claims remain allowed.

The objection to claims 17 to 19 and 20 to 28 by the Examiner, due to the omission of the expression "gradually", has been discussed at the oral interview and, as agreed, is considered not to be well taken. The present invention is not limited in scope to any gradual divergence or convergence since it covers a wide range of departure from the parallel condition of two straight wires, this range extending up to, but not including the well known 180 degree spaced dipole antenna. The specification as originally filed, in various parts thereof, is believed to adequately support this contention, attention being particularly invited to page 8 of the specification, the first paragraph thereof, which expressly states that although the preferred embodiment utilizes a gradual divergence, still this divergence is variable over a great range. A fair reading of the last

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paragraph of page 4 of the application also implies that this spacing does not depend upon gradual convergence, inasmuch as the divergence must be more than gradual to obtain any sort of desired radiant action if the antenna circuit is relatively short.

As regards the Examiner's statement that claims 20 and 22 are duplicates of each other, it is respectfully submitted that these the claims are not identical in scope, but differ in that claim 22 recites not only a pair of conductors, a limitation lacking in claim 20, but also omits reference to the excitation end of the antenna system, a limitation which is called for by claim 20. The omission of this particular feature from claim 22 is believed to render this claim slightly broader in scope than claim 20 and to be one which is necessary to give applicant the protection for his invention to which he is clearly entitled.

Claims 1, 3, 6 and 8 to 16 inclusive stand allowed.

Allowance of claims 17 to 19, 20 and 22, and 24 to 28 inclusive is now believed to be in order, and allowance is, therefore, requested so that this application may pass for issue.

Respectfully submitted,

S. E. LILIENFELD

By H. H. Gibbs
Attorney.

GHH:BG

Div. 51, Room 5628

Serial No. 698,147

MCG

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE

Nils E. Lindenblad, Akron. WASHINGTON February 23, 1933.
to Radio Corporation of America, a Corp. of Delaware.

NOTICE OF ALLOWANCE OF APPLICATION for a patent for an IMPROVEMENT in ANTENNAS FOR RADIO COMMUNICATION

filed Dec.24,1929 has been examined and ALLOWED with 25 claims.

The final fee, THIRTY DOLLARS, WITH $1 ADDITIONAL FOR EACH CLAIM ALLOWED IN EXCESS OF 20, must be paid not later than SIX MONTHS from the date of this present notice of allowance. If the final fee be not paid within that period, the patent will be withheld, but the application may be renewed within one year after the date of the original notice with a renewal fee of $30 and $1 additional for each claim in excess of 20.

The office delivers patents upon the day of their date, on which date their term begins to run. The preparation of the patent for final signing and sealing will require about four weeks, and such work will not be begun until after payment of the necessary final fee.

When the final fee is paid, there should also be sent, DISTINCTLY AND PLAINLY WRITTEN, the name of the INVENTOR, TITLE OF THE INVENTION, AND SERIAL NUMBER AS ABOVE GIVEN, DATE OF ALLOWANCE (which is the date of this circular), DATE OF FILING, and, if assigned, the NAMES OF THE ASSIGNEES.

If it is desired to have the patent issue to an ASSIGNEE OR ASSIGNEES, an assignment containing a REQUEST to that effect, together with the FEE for recording the same, must be filed in this office on or before the date of payment of the final fee.

After issue of the patent, uncertified copies of the drawings and specifications may be purchased at the price of TEN CENTS EACH. The money should accompany the order. Postage stamps will not be received.

The final fee will NOT be received from other than the applicant, his assignee or attorney, or a party in interest as shown by the records of the Patent Office.

NOTICE.—WHEN THE NUMBER OF CLAIMS ALLOWED IS IN EXCESS OF 20, NO FEE LESS THAN $30 PLUS $1 ADDITIONAL FOR EACH CLAIM IN EXCESS OF TWENTY CAN BE ACCEPTED AS THE FINAL FEE.

Respectfully,

Thomas E. Robertson
Commissioner of Patents.

H. G. Drewer,
C/o Radio Corp. of America,
570 Lexington Avenue,
New York, N. Y.

IF THE PRACTICE THE FINAL FEE GIVE THE SERIAL NUMBER AT THE HEAD OF THIS NOTICE.

IF UNSATISFACTORY CHANGES WILL NOT BE ACCEPTED.

1217

1005

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

June 20, 1937

Petition under **RULE 78:**

Application of

Serial No.

Invention:

This petition is referred to Examiner in charge of Division 51 in accordance with Order No. 2688; Order No. 2691, 508 O. G., 647, and Notice of August 11, 1922.

Thomas E. Robertson
Commissioner.

PAPER NO 15
AMENDMENT 4
(R 78)

UNITED STATES PATENT OFFICE

APPLICATION OF: H. E. LINDENBLAD

FOR: ANTENNAS FOR RADIO COMMUNICATION

SERIAL NO.: 329,147 FILED: December 24,1928

DIVISION: 51 ACOM: 5626

U.S PATENT OFFICE
JUN 19 1933
ISSUE DIVISION

MAIL DIVISION
JUN 16 33

Allowed Feb. 23 1933

New York, N. Y., June 16, 1933.

COMMISSIONER OF PATENTS

WASHINGTON, D C.

PATENT OFFICE
JUN 20 1933
DIV. FILED

DEAR SIR:

Please amend the above-entitled application under the provisions of Rule 78 as follows:

Claims 24, 26 and 27, last line, singularize "conductors" and add thereafter the word --system--.

Add the following claim:

24 A highly directional antenna system comprising a pair of electrical conductors which are disposed at an angle with respect to each other and serially connected together, said conductors having an overall length which is long relative to the operating wave length, high frequency apparatus, and means for connecting said apparatus to one end of one of said conductors, the other end of said connected conductor being connected to one end of the second conductor of said pair whereby high frequency energy flows through the entire length of one conductor and continues serially through the entire length of the other conductor, the conductors being adjusted in length and impedance so that radiant action occurs principally in the direction of a line perpendicular to the bisector of the angle between said conductors.

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REMARKS.

Claims 24, 25 and 27 have been amended in the interest of clarity to improve their form and to more adequately describe the idea set forth by the invention. Since the scope of these claims has not been changed one iota by this amendment it is thought that no objection will be raised with regard to the admission of this amendment, which is requested under the provisions of Rule 78.

One new claim 29 has been added which is quite specific to applicant's invention. This claim is directed to a system such as is illustrated by the upper half of Figure 8 wherein two serially connected conductors angularly disposed with respect to each other are connected to phase adjusters such as 40. The image of a system with merely the upper half would give a complete system including the lower conductors 23 and 24, as shown, and thus would completely include each and every element of applicant's arrangement. This claim is intended to protect applicant's contribution to the art which might thus be avoided by others who could otherwise utilize with impunity the teachings of applicant's invention by, for example, arranging the antenna conductors in a vertical plane and leaving off the lower half of the system. Applicant contemplates a vertical arrangement as being within the scope of his invention and describes same on page 7, second and third paragraphs of his specification. In view of the specific nature of this claim, which distinguishes over the disclosures of all other references by reciting, in a highly directional antenna system, such limitations as the serial flow of high frequency energy along conductors which are angularly disposed with respect to each other, and obtaining by means of desired length and impedance values radiant action in a direction of a line perpendicular to the bisector of the angle between the conductors, this claim, it is thought, is clearly allowable and such action is earnestly requested.

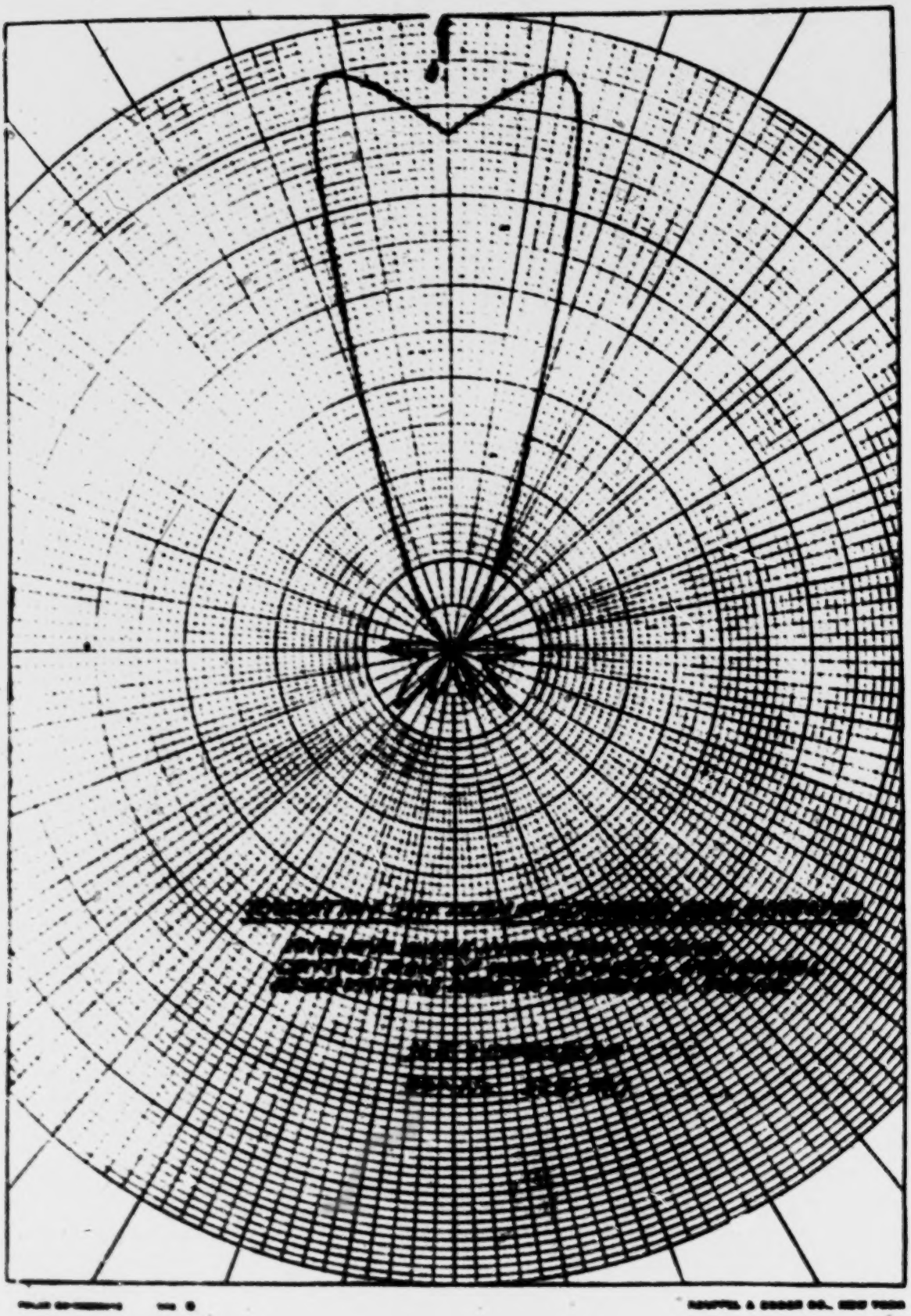
Early and favorable consideration of this amendment and its entrance under the provisions of Rule 78 is earnestly requested so that the application may soon pass for issue.

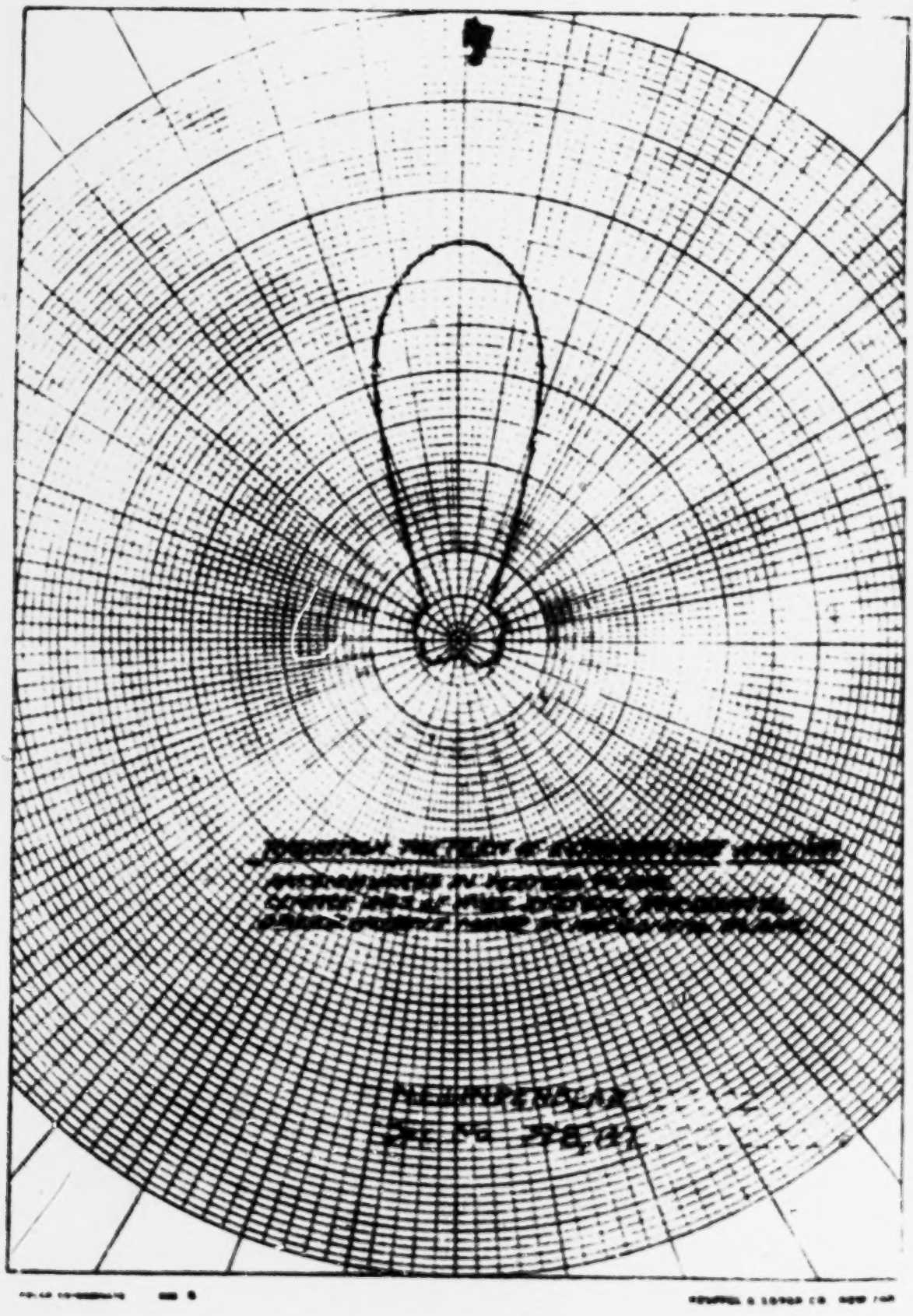
Respectfully submitted,

N. E. LINDENBLAD

By W. L. Glover
Attorney.

CHB:EC





Ex. 51 Room 3688 Paper No. 16

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

RBM:MCG June 21, 1933.

H. G. Grover,
C/o Radio Corp. of America,
570 Lexington Avenue,
New York, N. Y.

Applicant: H. E. Lindenblad

Ser. No. 688,147
Filed Dec. 24, 1933
For Antennas for Radio Communication.

The entry of the amendment proposed under Rule 78 has been disapproved. A copy of the examiner's adverse report appears below.

Thomas E. Robertson
Commissioner of Patents.

Responsive to amendment filed June 16, 1933.

The amendment to claims 24, 25 and 27 has been entered.

The proposed claim has not been entered since it is not apparent that an incomplete portion of the antenna as claimed herein would operate to give the desired result, particularly since no support for this change in the system is found in the specification.

Leo P. McCann
Action Examiner

K' M

APPROVED
JUN 22 1933
Asst. Commissioner of Patents.

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Aug. 2, 1933

Petition under **RULE 78:**

Application of

Serial No.

Invention:

This petition is referred to Examiner in charge of Division 51 in accordance with Order No. 3098; Order No. 3201, 398 O. G., 447, and Notice of August 11, 1922.

Commissioner.

NOTICE IS HEREBY GIVEN THAT I HAVE CHANGED MY ADDRESS TO

30 ROCKEFELLER PLAZA
NEW YORK, N. Y.

H G. GROVER

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1013

U. S. PATENT OFFICE

AUG 5 - 1933

UNITED STATES PATENT OFFICE

APPLICATION OF: N. E. LINDENBLAD

FOR: ANTENNAS FOR RADIO COMMUNICATION

SERIAL NO.: 328,417 FILED: December 24,1928

DIVISION: 51 ROOM: 5828

LAST OFFICE ACTION: June 21, 1933.

MAIL DIVISION AUG 7 1933 PATENT OFFICE

AUG 7 1933

New York, N. Y., August 3, 1933.

COMMISSIONER OF PATENTS

WASHINGTON, D. C.

DEAR SIR:

Reconsideration of the Examiner's refusal to enter proposed claim 29 under the provisions of Rule 78 is respectfully requested.

The statement of the Examiner that it is not apparent that an incomplete portion of the antenna as claimed therein would operate to give the desired result has been noted and applicant submits herewith a photostatic copy of a letter received from the inventor as proof that such an arrangement as defined in the claim will inherently function. It is earnestly submitted that the operation of such an arrangement should be obvious to anyone skilled in the art from a mere reading of applicant's disclosure and is a very natural detail of the system described. As appears in the attached letter, to which the Examiner's attention is respectfully invited, the theory or images as first developed by Lord Kelvin has time and again been used and proved, especially in the radio art and also in other branches of the electrical art.

The attached letter, it is submitted, is indeed persuasive evidence, and is considered to be sufficient proof, that the system of the proposed claim does inherently function as

stated, and is a very natural detail of the system, obvious to anyone skilled in the art.

In view of the foregoing, it is submitted that claim 8 defines an arrangement to which applicant is clearly entitled and one which is necessary to give him the protection he needs for his invention.

Applicant at this time wishes to thank the Examiner for the very courteous interview kindly granted to him.

Respectfully submitted,

S. B. LIEBERMAN

By _____
Attorney.

Cl. 29 in paper 15

ENTRY RECOMMENDED
UNDER RULE 70.

_____
EXAMINER

GEB:BG
Enclosure.

R.C.A. COMMUNICATIONS, INC.

To: Mr. C. E. Brown, Patent Dept. PATENT DEPARTMENT Rocky Point, New York July 24, 1933
From: Mr. H. B. Lindenblad RECEIVED File No. I-100
Subject: Lindenblad Docket 2961 JUL 25 1933

Dear Mr. Brown: Answered

I have your letter of July 17, 1933 calling my attention to the fact that the Examiner has raised some question with regard to the operativeness of the system defined in our claim 29 which was proposed under Rule 78, wherein merely the upper half of the system of our Figure 5 may be used with an image in the ground.

It is surprising that the Examiner has raised this question since the operation of such an arrangement should be obvious to anyone [illegible] of the system.

I believe it requires no argument that one half of the system with an image in the ground functions as is claimed to obtain radiant action principally in the direction of a line perpendicular to the bisector of an angle between the conductors of half the system. The theory of images as first developed by Lord Kelvin has [illegible] and proved, especially in the [illegible] of the electrical art. It is one of the axioms on which we build our theories of propagation and is an accepted fact. Thus, for instance, in the case of a half wave doublet away from any reflecting or image surface we have a radiation resistance of about 72 ohms. If we now cut our doublet at the middle and take such a half and place it at right angles with a reflecting surface, letting one end of the wire touch the surface, we have a quarter wave antenna of exactly half the radiation resistance. This is a widely used arrangement in the broadcasting field. In many instances, especially at the longer waves, when for instance the dimensions of such a wire would call for unreasonably high supporting structures, extra capacity is added at the top and extra inductance is added at the bottom in order to permit tuning. In the calculation of any of these systems, the procedure is, however, always the same; the consideration of the image. When, for instance, the capacity of an antenna is calculated, it is calculated between the real structure and its image. The surface of the ground is then the symmetrical dividing surface. The capacity obtained by calculating in this manner is then considered as consisting of two capacities in series, the one between the real structure and the surface and the other between the surface and the image. The actual capacity is then the capacity of one of these, or twice the capacity of the two in series. The calculation of radiation resistance applies identical reasoning. The radiation resistance of a doublet is 72 ohms. If half of such a doublet is an image, the actual system,

which is then only a quarter wave radiator, has half the radiation resistance; the value of one of two resistances in series. In most cases the reflecting, or image forming surface, which is earth itself, is, of course, not perfect. Therefore certain deviations take place which have to be taken into account. This, however, does not detract from either the general theory or the results. They are only correction factors.

Now in case of our particular antenna system. It is a symmetrical structure around the axis of maximum radiation. If we therefore locate a conductive plane to include this axis and also to be at right angles with the plane of the wires we have in no way disturbed the system. The conductive plane is in a neutral region. The two halves, one on each side of the plane, are in series. If we now throw away one half and let earth itself be the conductive plane, we have the antenna system set forth in your proposed claim. Such an arrangement is in accordance with the principles of our invention [illegible] and is [illegible] in the claim. The total radiation resistance of such a system will then be one half of the radiation resistance of the double system, save for the corrections that will have to be made for the imperfection of the soil.

I hope the above will aid you in clearing up the objection raised by the Examiner since we are clearly entitled to a claim such as we propose covering the very obvious and natural detail of our general system utilizing an image in the ground.

If the above explanation does not suffice, I shall be very happy to supply further proof, either by affidavit or of a mathematical nature, that the system defined in the claim functions correctly and as we propose. However, in view of the fact that the theory of operation of the system has been proven time and time again, as I have mentioned before, and is so well known to all engineers, I hardly think that further proof will be required to prove our contention.

Very truly yours

H. E. Lindenblad

HEL/HVH

229

1017

Mr. 01 Room 5628 RPK:B

Address only The Commissioner of Patents, Washington, D. C. and not to any official by name

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Paper No. 18

All communications concerning this application should give the serial number, date of filing, and name of the applicant.

August 11, 1933

E. O. Grover
c/o Radio Corp of America
30 Rockefeller Plaza,
New York, N.Y.

Applicant: Ellis E. Bindenbled

Ser. No. 688,147
Filed Dec. 24, 1932
For Antennas For Radio Communication

The amendment proposed has been entered under Rule 78.

[redacted]
Commissioner of Patents.

Mr. ...

THE FINAL FEE WILL NOT BE $24.00

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Aug. 17, 1933

Petition under **RULE 78:**

Application of

Serial No.

Invention:

This petition is referred to Examiner in charge of Division 51 in accordance with Order No. 2888; Order No. 2801, 398 O. G., 447, and Notice of August 11, 1922.

[redacted]
Commissioner.

Form 10-4000

PAPER NO. 19
AMENDMENT A

AUG 17 33
U. S. PATENT OFFICE
AUG 17 1933

UNITED STATES PATENT OFFICE

APPLICATION OF: E. E. LINDENBLAD

FOR: ANTENNAS FOR RADIO COMMUNICATION

SERIAL NO.: 699,147 FILED: DEC. 24, 1932

DIVISION 51 ROOM 5628

PATENT OFFICE
AUG 17 1933
FILED

New York, N. Y., August 15, 1933

COMMISSIONER OF PATENTS,
WASHINGTON, D. C.

DEAR SIR:

Please amend the above-entitled application under the provisions of Rule 78 as follows:

Page 7, after the third paragraph, add the following paragraph:

In connection with Figures 3 and 5, the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground; we will then have two serially connected conductors (conductor 23 and the upper antenna leading to transmission line 24 in Figure 5). Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors.

REMARKS

Applicant is submitting herewith a short paragreph for insertion in the application under the provisions of Rule 78 in order to amplify and clarify the specification. No objection, it is thought, will be raised to the entrance of this amendment which is clearly within the scope of the invention; which is respectfully requested.

Respectfully submitted,
H. E. LINDENBLAD

By H. E. Lindenblad
Attorney

CHB:B

ENTRY RECOMMENDED
UNDER RULE 78

EXAMINER

Div. 51 Room 5628 Paper No. 20

Address only "The Commissioner of Patents, Washington, D. C." and not any official by name MCC

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON August 18, 1928.

H. O. Grover,
C/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N. Y.

Applicant W. R. Lindenblad

Ser. No. 328,147
Filed Dec. 24, 1928
For Antennas for Radio Communication.

The amendment proposed has been entered under Rule 78.

[redacted]
Commissioner of Patents.

AUG-23 33 033 013 A ~Check — 30.0

AUG-23 33 033 013 A ~Check — 4.0

MAIL DIVISION AUG 23 33

U. S. Patent Office

UNITED STATES PATENT OFFICE

APPLICATION OF: B. E. Lindenblad

FOR: Antennas for Radio Communication

SERIAL NO: 528,147 FILED: Dec. 24, 1928

DATE OF ALLOWANCE: Feb. 28, 1933

August 22, 1933

Hon. Commissioner of Patents

Washington, D. C.

Sir:

We are sending you herewith a check number 90105, for $34.00 to pay the final fee on the above identified application.

Respectfully,

B. E. LINDENBLAD

by H. E. Gross

Attorney

Radio Corporation of America
30 Rockefeller Plaza
New York

AGG:MH
ENCL.

No. 51 Room 5618 DEPARTMENT OF COMMERCE Paper No. 21
UNITED STATES PATENT OFFICE
WASHINGTON

[redacted] ER:1106 September 6, 1923.

Please find below a communication from the EXAMINER in charge of this application

[redacted]
Commissioner of Patents.

H. G. Grover,
C/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N. Y.

Applicant: E. E. Lindenblad

Ser. No. 328,147
Filed Dec. 24, 1918
For [redacted] Communication.

SEP 8 1923

In accordance with the provisions of Order No. 2288, dated March 12, 1917, which reads in part as follows:

. . . . . .

Obvious informalities in the application may be corrected by the examiner, but said corrections must be in the form of an amendment, approved by the Principal Examiner in writing, placed in the file, and made a part of the record. The changes specified in the amendment will be entered by the clerk in the regular way.

. . . . . .

the changes, hereinafter specified, are made by the examiner in the application above identified.

Should these changes not be satisfactory to the applicant, appropriate amendment may be proposed under the provisions of Rule 78, provided the specification has not been printed.

The application has been amended as follows:

(original claim 10)

/ In claim 7, line 3, "directional" has been changed to direction.

R. O. Backus
Examiner

RM

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FILED
APR 24 1934

District Court of the United States

Eastern District of New York

Commissioner of Patents,
Washington, D. C.

Sir:

In compliance with the Act of February 18, 1922 (42 Stat. L. 388), you are advised that there was filed on the 21st day of April, 1934, in this court an action, suit, or proceeding No. E-7234, entitled:

Name: Radio Corp. of America, Plaintiff,
Address: Delaware Corp.

Name: Marconi Radio & Telegraph Co. of Am., Defendant,
Address: Delaware Co., N.Y.

brought upon the following patents:

PATENT NO.	DATE OF PATENT	PATENTEE
1. 1,623,996	April 10 1927	Philip J. Carter
2. 1,909,610	May 16 1933	Philip J. Carter Radio Corp.
3. 1,844,006	Oct. 26 1931	Nils E. Lindenblad
4. 1,924,502	April 19 1933	
5.		

In the above-entitled case, on the _____ day of _____, 19__, the following patents have been included by _____ (insert amendment, answer, cross bill, or other pleading):

PATENT NO.	DATE OF PATENT	PATENTEE
1.		
2.		
3.		
4.		
5.		

In the above-entitled case the following decision has been rendered or decree issued:

IN WITNESS WHEREOF I have affixed my hand this 23rd day of April, 1934, at Brooklyn, N.Y.

_____, Clerk of said Court.

by H.

Deputy Clerk.

63

51 23

TITLE REPORT

No. 1,927,522

Name H. E. Lindenblad

The title appears from the assignment records to be vested in:

Radio Corporation of America, a corp. of Del.

Examined up to and including 5/23/34

This certificate dated 6/2/34

C. H. Gray
Chief of Assignment Division.

No further assignments appear to have been received for record including 5/29/34

64

1237

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INTERFERENCE

Interference No. 68973 Paper No. 24

Name, Nils E. Lindenblad

Serial No. 328,147 - Pat. No. 1,927,522

Title, Antennas for Radio Communication

Filed, December 24, 1928 - Pat'd. Sept 19, 1933

Interference with Edmond Bruce

DECISIONS ON MOTION

Ex'r of Interferences, ... Dated, ...

Board of Appeals, ... Dated, ...

DECISIONS ON PRIORITY

Ex'r of Interferences, ... Dated, ...

Board of Appeals, ... Dated, ...

Court, ... Dated, ...

REMARKS:

This should be placed in each application or patent involved in interference in addition to the Interference letter by Primary Examiner.

1926

1238

(Fer.Intf.Div., June 12,1934)

No. 51 Room 5628

Paper No. 25

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

REM:MCG

Please find below a communication from the EXAMINER in charge of this application

By copy furnished, Commissioner of Patents

Applicant: H. E. Lindenblad

H. G. Glover,
C/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N. Y.

Ser. No. 688,147
Filed Aug. 24, 1933
For Antennae for Radio Communication.
Patent No. 1,987,882, granted Sept. 18, 1934.

The case, above referred to, is forwarded to the Examiner of Interferences because it is adjudged to interfere with others, hereafter specified. The question of priority will be determined in conformity with the Rules. The interference will be identified as No. 68973 On or before SEP 4 1934

the statement demanded by rule 110 must be sealed up and filed with the subject of invention, and name of party filing it, indorsed on the envelope. The subject-matter involved in the interference is

1. A uni-directional antenna comprising a diverging pair of conductors excited in phase opposition, diverging only in the desired direction of radiant action.

2. A highly directional antenna system comprising wires which are long relative to the length of the communication wave excited in phase opposition, which first diverge from the excitation end and then converge successively, whereby radiant action occurs predominantly in a direction substantially through the opposite apices of the wires.

3. A uni-directional antenna system comprising a diverging pair of conductors, the said conductors being long relative to the length of the communication wave, and means for producing traveling waves thereon whereby radiation is predominantly along the approximate direction of the length of the conductor system.

4. A highly directional antenna system comprising a pair of electrical conductors which are disposed at an angle with respect to each other and serially connected together, said conductors having an overall length which is long relative to the operating wave length, high frequency apparatus, and means for connecting said apparatus to one end of one of said conductors, the other end of said connected conductor being connected to one end of the second conductor of said pair whereby high frequency energy flows through the entire length of one conductor and continues serially through the entire length of the other conductor, the conductors being adjusted in length and impedance so that radiant action occurs principally in the direction of a line perpendicular to the bisector of the angle between said conductors.

The interference involves your patent above identified;

and

SHEET 100 - 388,147

An application for Directive Antenna, filed by Edmond Bruce, whose Post-Office address is 27 Buena Place, Red Bank, New Jersey, whose attorneys are John G. Roberts and Elmer W. Griggs, 463 West Street, New York, N. Y., whose associate attorney is G. T. Morris, 463 West Street, New York, N. Y., and whose assignees are Bell Telephone Laboratories, Inc., of New York, N. Y., a Corporation of New York.

The relation of the counts of the interference to the claims of the respective parties is as follows:

Crumb:	Lindenblad	Bruce
1	13	17
2	14	18
3	20	19
4	24	20

EM

J. D. Roberts

Examiner

DEFENDANT'S EXHIBIT V V

1974387

PATENT NO.

460467

1930

DATED SEP 18 1934

DIV. 1 51

(EX'R'S BOOK) 76-92 E

PHILIP STAATS CARTER

Assr (1) to Radio Corporation of America, a corp of Delaware

PORT JEFFERSON,

NEW YORK

ANTENNAE

ORIGINAL

RENEWED

APPLICATION FILED COMPLETE JUNE 11, 1930 .53

Petition, Specification,

Oath, Power, Etc. JUNE 11, 1930

1 sheet drawings,

2 EXTRA CLAIMS JUNE 11, 1930

Examined and passed for issue

Date of Allowance Jan. 13, 1934

Issue Fee $30 Aug 23, 1934

Attorney H. B. GROVER C/O RADIO CORP OF AMERICA 5-76 Broadway NEW YORK N.Y.

5-76 Broughton Ave.,

Assistant Attorney

No. of Claims Allowed 21 Print Claim 3

This is Allowed Antenna

In O. G. Class 250-33

SPECIAL

CASE PENDING OVER 3 YEARS

1930

CONTENTS:

1		[illegible]	31.
2		March 4, 1931	32.
3	City of Cedar	April 23 1931	33.
4	Amendt A	Sept 2 1931	34.
5	Amendt B	Nov 12 1931	35.
6	By	March 2 1932	36.
7	Amendt C	Aug 6 1932	37.
8	By	Nov 8, 1932	38.
9	Amendt D	May 9 1933	39.
10	[illegible]	[illegible]	40.
11	Letter	Aug 8, 1933	41.
12	AMENDMENT E	JAN 18 1934	42.
13	AMENDMENT F	FEB 10 1934	43.
14	Cap	April 11, 1934	44.
15	AMENDMENT G	May 3 1934	45.
16	Amendt H	May 15 1934	46.
17	Orphanage amendt I	May 17, 1934	47.
18	Amendt J Ord Creek Park	July 11 1934	48.
19	[illegible]	July 16 1934	49.
20	Amendment to K	Aug 3 1934	50.
21	Letter of Entry	Aug 16 1934	51.
22	Amendt to L	Aug 22, 1934	52.
23	Letter of Entry	August 23 1934	53.
24			54.
			55.
			56.

— date

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27.00

JUN 19 30

C.B.U.S. PAT. OFFICE

460467

PATENT OFFICE

JUN 18 1930

PETITION

Div. filed

TO THE HONORABLE COMMISSIONER OF PATENTS:

Your petitioner, PHILIP STAATS CARTER

a citizen of the United States, residing at Port Jefferson, Long Island,

in the County of Suffolk State of New York

whose Post Office address is Port Jefferson, Long Island, New York,

prays that Letters Patent may be granted him for the improvement in

ANTENNAE

set forth in the accompanying specification.

And he further prays that you will recognize H. G. Grover, care of Radio Corporation of America, 233 Broadway, New York, as his attorney, with full power of substitution and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent Office connected therewith.

Philip S. Carter

Jr

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, PHILIP STAATS CARTER, a citizen of the United States, and a resident of Port Jefferson, Long Island, New York, have invented certain new and useful improvements in

[illegible]

of which the following is a specification:

760

-1-

This invention relates to antennae and especially to directional antennae or antennae systems.

If a wire long, relative to the working wave length; namely, a plurality of half wave lengths long, is excited in a fashion such that standing waves are produced thereon, radiation will occur principally in the direction of symmetrical cones having their apices at the center of the wire. In cross section, the radiation characteristic would appear as symmetrical hollow cones about the wire.

An object of the present invention is to utilize this phenomenon for the directive radiation of electromagnetic energy. To do so, a pair of wires or linear conductors long relative to the working wave length are disposed at an angle such that principal radiation takes place along the bisector of the angle. This angle, in general, corresponds to the angle of the principal cone of radiation about one of the conductors.

Still a further object of the present invention is to disclose the proper angle for conductors or radiators either an even number of half wave lengths long or an odd number of half wave lengths long, and, in general to disclose the angle for best directional propagation for wires of any finite length.

A pair of conductors disposed in the manner described will radiate equally well in two directions, namely, towards the diverging end of the wires and towards the converging end of the wires. That is to say, the antenna system so far described is bidirectional.

A further object of the present invention is to provide a unidirectional arrangement. This may be accomplished by placing a similar parallel pair of wires an odd number of quarter wave lengths away from the wires forming the antenna proper in a direction taken along the bisector of the angle formed by the wires. The second pair of wires may be left unenergized or floating or they may be energized in proper phase such that for one direction radiation cancellation occurs, whereas in the other direction there is strengthening of propagated electromagnetic waves.

To concentrate the beam in a transverse plane, relative to the plane of the pairs of wires, usually the vertical plane, since the pairs are ordinarily disposed in horizontal planes, another object of the present invention; and this is accomplished by placing similar pairs of wires in planes parallel to the planes of the first mentioned pairs of wires the planes being spaced apart, preferably, at least a half wave length.

To additionally concentrate the beam of energy radiated, systems of the nature utilized heretofore may be placed in broadside whereby there is added concentration of the radiated beam of energy in a horizontal plane, and, by placing more systems or stories of systems above one another, there will be added concentration of a beam in a vertical plane.

The invention is further described in connection with the accompanying drawing, in which

Figure 1a illustrates, generally, the principal radiational characteristic of a long conductor upon which standing waves are produced,

Figure 1b illustrates in cross section, the radiation characteristic of a wire five wave lengths long,

Figures 2a, 2b and 2c indicate various forms of the fundamental unit of the present invention wherein long linear conductors having standing waves thereon are disposed at an angle such that principal radiation occurs along the direction of the bisector of the angle,

Figure 3 indicates the bidirectional characteristic of any of the figures 2a, 2b, or 2c one of the units shown in figure 2.

Figure 4 illustrates an antenna system for concentrating the directional beam radiated from one of the units shown in figures 2a, 2b and 2c figure 2,

Figure 5 illustrates the arrangement of a plurality of units such as shown in figure 2 for obtaining unidirectional propagation,

Figures 6 and 7 illustrate, respectively, the power distribution in the horizontal and vertical planes from an antenna system such as shown in figure 5, system such as shown in figure 5,

Figure 8 illustrates a broadside arrangement of unidirectional units for further increasing the directivity of a propagated beam of electromagnetic waves,

Figure 9 indicates, in plan view, an end-on or in line arrangement of units for increasing the directivity of a beam of waves,

Figures 10 and 10a indicate diamond shaped arrangements of units for obtaining unidirectional propagation,

Figure 11 illustrates a preferred form of the invention for concentrating a unidirectional beam of energy horizontally and vertically, when the length of wires is of the order of 8 to 12 wave lengths, and,

Figure 12 is a graph showing the proper relationship, according to the present invention, between the length of a single conductor of a pair of conductors and the angle to be given it relative to a desired direction of propagation.

In general, as shown in figure 1a, about a wire 2 long, relative to the working wave length, there are two principal hollow cones 4, 6 of radiation. The cones are symmetrical about the wire 2, and the axis of the cones coincides with that of the radiator 2. For a given wire, at a given wave length, the angle α between the axes Y-Y, of each lobe or ear of the cone which appears as such in cross section, and the wire 2 is constant.

More specifically, a cross section of the solid polar diagram of a wire, a number of wave lengths long, and bearing standing waves thereon, contains as many ears per quadrant as there are wave lengths in the wire. Thus, as shown in figure 1b, for a wire five wave lengths long, there are five ears in each quadrant, the principal lobes of radiation occurring along the axes Y-Y, As indicated, the instantaneous directions of the field represented by each ear is reversed.

Now, if it is desired to radiate energy principally in the direction of axis X-X of figure 2, the conductors, shown in figure 1, should be turned an angle α relative to the direction X'-X; and, in order to increase still further the directional characteristic along the axis X-X, according to the present invention, two wires are used, which make an angle α with the axis X'-X on opposite sides of the axis in a fashion such that the axis and the pair of wires lie in a single plane. In directions other than along the axis X-X, radiation cancellation will occur mainly as a result of which, a pair of wires disposed at an angle α with respect to the X-X axis will have a radiation characteristic in the plane of the pair of wires such as shown in figure 2.

By considering a long wire the equivalent of a very large number of very short, (Hertz) oscillators and by adding up the field components at any point P having a direction angle θ relative to the axis of the wire where the point P is a great distance from the wire as compared to the length of the wire such that all lines from point P to any point on the wire are essentially parallel, it can be shown that the field strength is given by the following proportionality for a conductor an even number of half wave lengths long:

$$E \propto \left(\frac{\cos\left(\frac{n}{2}\frac{\pi}{\lambda}\cos\theta\right)}{\sin\theta} \right)$$

The letter "n" indicates the number of half wave lengths contained in the wire.

For a wire an even number of half wave lengths long, in similar fashion, the field strength "E" is given by the following proportionality:

$$E \propto \left(\frac{\sin\left(\frac{n}{2}\frac{\pi}{\lambda}\cos\theta\right)}{\sin\theta} \right)$$

Where n as above indicates the number of half wave lengths on the wire.

The value for which the angle θ in either of the above equations makes the expression a maximum value gives, of course, the value for the angle at which such wave front should be disposed relative to the direction X-X of desired wave propagation. The obtaining of the critical value of θ for either of the above equations may be readily determined; its value for wires up to fourteen wave lengths long is given graphically in Figure 18. For practical purposes the empirical formula

$$\theta = 90.0 \left(\frac{\quad}{\quad}\right)^{-0.833} \text{ degrees}$$

where l equals the length of the wire and λ the wave length, both in the same units of measurement, ~~is sufficiently accurate. Where a pair of wires are used in accordance with the present invention~~ they should be spaced apart at an angle equal to twice the angle α as determined in any of the ways described above.

In order to obtain a bidirectional unit having a characteristic such as shown in figure 3, as already indicated, any of the arrangements shown in figure 2 may be utilized. The fundamental unit is shown in figure 2a where a transmission line 10 supplies high frequency energy to a pair of wires A,B forming the angle 2α with each other. The angle α is the angle made by one of the conductors with the X-X axis along which it is desired that the radiators A,B, propagate energy. The conductors A,B, are joined together at their apex which falls in the axis X-X as shown. The wires are fed intermediate their ends in a fashion similar to that in which a half wave length oscillator is fed intermediate its ends. ~~If desired, of course, as shown in figure 6, the transmission line 10 may terminate in the extremities of linear radiators A,B, rather than connect them together.~~

The arrangement shown in figure 2a is, however, preferred because it facilitates ease of tuning of the antenna unit comprising the pair of wires A,B. The transmission line 10 feeds energy to a U-shaped loop 12, the legs of which are shunt circuited by an adjustable short circuiting stump 14, representing a voltage nodal point. The legs 16 of the loop 12 supply energy in phase opposition to ~~balancing the conductors A,B. Adjustment of impedance such that there is no reflection along transmission line 10 is accomplished along~~ the legs of the loop by suitable adjustable tapping points 18.

Use of the loop allows of completion of the tuning of the antenna wires by making the total effective tuning length of each wire of the V or radiating unit, equal to an odd number of quarter wave lengths. The effective radiating length is the length of wire included in the "V" only, since the loop is non-radiating and can be made of any length.

When tuning of the V is properly accomplished by the U-loop, the system presents a pure resistive load to the transmission line. By tapping the line to the legs of the U at a suitable distance from the short circuiting strip, the effective resistance of the antenna system can be made equal to the surge impedance of the line, which is a necessary condition for maximum transmission efficiency.

It should be mentioned here that energy to the radiators A,B should always be fed thereto out of phase for otherwise at a distant point P along the axis X-X there would be radiation cancellation; and, it is to be understood that the unit so far described is not only useful for radiation purposes but may be utilized equally as well for reception. That is, the antenna system according to the present invention is equally well suited for any type of radiant action whether it be collection of radiation energy or the transmission thereof.

However, it should be clearly understood that the wires of each unit can be of any length whatsoever provided they are placed at the correct angle for their particular length. For best tuning, the total over-all length of both of the wires and the U loop terminating them should be effectively an integral number of half wave lengths, but the portion forming the radiation element can be of any length. The law giving the correct angle for lengths between odd and even number of half wave lengths is not given due to its complexity, but, the empirical formula and the curve of figure 18 will be found accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths.

1251.

In order to prevent undesired high angle radiation, and in order to concentrate the desired beam in elevation, the scheme shown in figure 4 may be utilized. Here, pairs of wires A,B and A', B' are placed in parallel horizontal planes and supported by masts 20 and suitably insulated therefrom by suitable insulators 28. Both pairs of wires or units are fed cophasally from a transmission line 24 through conductors 26, the wires of each pair or unit being fed in opposite phase. In order to increase the elevational concentration of radiated energy, the pair A,B and the pair of wires A' and B' are placed apart in horizontal planes ~~by any convenient spacing preferably not less than one half wave length apart, and preferably at least, one-half wave length apart.~~ The lower pair should be at least one-half wave length above ground. Bidirectional propagation ensues along the axis X-X' but in a much more concentrated form relative to the use of a single unit.

The vertical spacing of the units one above the other need not to made an integral number of half wave lengths. In addition, it should be noted that for wires several wave lengths long, vertical radiation is either zero or practically very small. ~~Specifically, it is zero for wires whose lengths are equal to an even number of half wave lengths, and small for wires an odd number of half wave lengths long. For wires whose length approaches~~ wires whose lengths approach, the order of magnitude from 6 to 10 wave lengths, a spacing greater than one-half wave length is preferred.

In practice, where the height of the antenna is limited by economic considerations and wherein it is desired to make ground absorption as low as possible, a good compromise is a half wave length spacing. For transmission of energy having a wave length of 17 or 18 meters, a good practical antenna may be had wherein the lower wires are about three-quarters of a wave length above ground, and the spacing between wires is one-half wave length. Eighty foot poles or masts may be used to support the wires.

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In order to obtain a unidirectional radiation characteristic, pairs of units such as shown in figure 2 may be spaced parallel and apart a distance along the axis X-X or the bisector of the angle formed by each pair of wires in each unit a distance equal to an odd number of quarter wave lengths.

Such a system combined with means for concentrating the beam in a direction traversing the plane of the wires of each unit is shown in figure 5. That is, figure 5 illustrates a system such as shown in figure 4 duplicated in a direction along the X'-X axis whereby, in a horizontal plane, a directional characteristic is obtained such as that shown in figure 6 and, in a vertical plane a power distribution characteristic such as shown in figure 7.

The system of figure 5, comprising the pair of wires A,B paralleled by similar pairs a, b spaced apart along the direction X'-X an odd number of quarter wave lengths and, as shown nine-quarters of a wave length behind the apex 23 of wires A,B, is excited so that the wires a, b, have standing current waves thereon 90 degrees ahead in phase of the standing current waves on wires A,B. Consequently, energy will be propagated principally along the axis X'-X towards the diverging ends of the radiators. In order to concentrate the beam of energy so radiated, similar pairs of radiators are placed below the pairs A,B and a, b in planes suitably spaced from the first mentioned pairs of radiators to obtain the desired vertical or elevational concentration. The lower pairs of radiators are excited cophasally with the upper pairs through conductors 26, 26' fed by transmission line 24. In order to tune the various units, U-shaped loops 30, 30' are provided, short circuited by straps 32, 32'.

By reversing the exciting wires a, b 90 degrees lagging relative to radiators A, B, unidirectional propagation may be obtained in an opposite direction, or, towards the converging ends or apices of the units.

If greater concentration of the radiated energy is desired, several systems such as shown in figure 8, for example, comprising an effective radiating unit A, B and an effective reflecting unit a, b may be placed in succession and excited cophasally. Thus, in figure 8 each of the radiating units A, B shown in plan view is provided with a reflecting unit a, b. By means of crossed transmission lines as shown diagrammatically at T each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves on the units.

The units may be arranged in end-on fashion or coaxially as shown in figure 9 where each of the units U is spaced apart in the direction of desired propagation. By making the phase difference between each of the units equal to $\frac{2\pi}{\lambda} S$ (where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression.

Other combinations will readily suggest themselves to those skilled in the art, for example, the units U may be placed diamond shaped fashion such as shown in figure 10, or, they may be superimposed as shown in figure 10a, the wires of each unit traversing each other.

In order to obtain greater concentration of the radiated beam of energy in a direction traversing the plane of each unit, the systems may be extended in the fashion shown in figure 11. Here, the system of figure 8 has been duplicated in a vertical direction, giving increased concentration of the beam in elevation. Energy is fed to the system through an impedance matching device 40 and thence coplanally to the reflecting units through a suitable connection 42. Energy is similarly fed to the radiating units through a suitable connection 44. By suitable tuning and by suitable spacing of the radiating pairs of wires and reflecting pairs of wires, unidirectional propagation may be obtained in either direction along the bisector of the angle formed by the wires of each pair.

The spacing of the antenna and reflector, of the system shown in figure 11 where the wires are 6 to 12 wave lengths long, is made preferably nine-quarters of a wave length. For wires longer than ten wave lengths, the preferred form should have a greater spacing between the antenna and reflector such as two and three-quarters or three and one-quarter wave lengths. For wires on the order of three or four wave lengths long, the reflector spacing from the antenna should be one and one-quarter wave lengths or less. In general, for maximum concentration, as the length of wires in terms of wave lengths increases, the reflector and antenna spacing should be increased.

In each of the systems, of course, for reception, the transmission line would simply be coupled to a suitable receiver, the antenna being directed upon a transmitting station. The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention. And, during transmission it may often be found desirable to have the plane of the wires tilted away from the earth and towards the direction in which the beam of energy is to be propagated.

(7)

Having thus described my invention, what I claim is:

1. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended, and means for exciting the radiators in phase opposition whereby radiation of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors.

2. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended, and, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

3. A directional antenna comprising a pair of angularly disposed linear conductors disposed in a horizontal plane, each substantially a plurality of half wave lengths long and means for producing standing waves thereon whereby radiation of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors.

4. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended and disposed in a horizontal plane, and, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

5. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and having standing waves thereon whereby radiation of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors parallel and similar to said first mentioned pair of conductors and spaced therefrom an odd number of quarter wave lengths measured in a direction along the bisector of the angle formed by the conductors.

8. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended; means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators; and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors, an odd number of quarter wave lengths.

9. A directional antenna comprising a pair of angularly disposed linear conductors disposed in a horizontal plane, each substantially a plurality of half wave lengths long, and means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

10. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long and open-ended and disposed in a horizontal plane; means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators; and, another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of quarter wave lengths.

5. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long, and having means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and, another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair in a direction traversing the planes of each pair.

6. A directional antenna comprising a pair of angularly disposed linear conductors, each substantially a plurality of half wave lengths long, and having means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors; and, another pair of conductors similar to said first mentioned pair of conductors spaced apart from said first mentioned pair, in a direction perpendicular to the planes of the pairs of conductors a number of half wave lengths.

7. An antenna comprising parallel pairs of angularly disposed conductors, spaced apart along the direction of the bisector of the angle formed by the conductors an odd number of quarter wave lengths, and, similar pairs of conductors in planes parallel to and spaced apart vertically from the planes of the first mentioned pairs of conductors.

8. A transmitting antenna system comprising parallel pairs of angularly disposed conductors arranged in a horizontal plane having their apices spaced apart an odd number of quarter wave lengths, and similar pairs of conductors disposed in a parallel horizontal plane a distance away from said first mentioned plane, equal to one or more half wave lengths.

13. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle equal to twice the angle for which the expression $\frac{\cos(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum, n being the number of half wave lengths contained in each conductor.

14. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to twice the angle for which the expression $\frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum, n being the number of half wave lengths contained in each conductor.

15. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle equal to twice the angle for which the expression $\frac{\cos(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum, and a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

16. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to twice the angle for which the expression $\frac{\sin(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum, and a similar pair of conductors spaced from said first pair by an odd number of quarter wave lengths in a direction along the bisector of the angle of the conductors.

17. An antenna comprising a pair of linear conductors, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle equal to twice the angle for which the expression $\frac{\cos(n\frac{\pi}{2}\cos\theta)}{\sin\theta}$ is a maximum, and a similar parallel pair of conductors away from the first mentioned pair in a direction perpendicular to the planes of the pairs.

Page Tightly Bound

1418. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed at an angle substantially equal to twice the angle for which the expression $\left(\frac{\sin\left(\frac{\pi}{\lambda}\cos\theta\right)}{\sin\theta}\right)^2$ is a maximum, and a similar pair of conductors away from the first mentioned pair in a direction perpendicular to the planes of the pairs.

1520. An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice $50.8\left(\frac{1}{\lambda}\right)^{-0.513}$ degrees.

1620. An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice $50.8\left(\frac{1}{\lambda}\right)^{-0.513}$ degrees, and, a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors.

1722. An antenna comprising pairs of long conductors, the conductors of each pair disposed at an angle substantially equal to twice $50.8\left(\frac{1}{\lambda}\right)^{-0.513}$ degrees, and the pairs being placed in parallel planes substantially an odd number of half wave lengths apart.

1822. An antenna comprising pairs of relatively long conductors the conductors of each pair being disposed at an angle substantially equal to twice $50.8\left(\frac{1}{\lambda}\right)^{-0.513}$ degrees the apices of each pair being separated by an odd number of quarter wave lengths; and, similar pairs of conductors in a substantially parallel planes spaced apart from said first pairs.

Chief Clerk Secretary Carter

1048

AFFIDAVIT

STATE OF New York)
COUNTY OF Suffolk) SS:

PHILIP STAATS CARTER the above named petitioner, being duly sworn, deposes and says that he is a citizen of the United States and resident of Port Jefferson in the County of Suffolk, State of New York, and that he verily believes himself to be the original, first, and sole inventor of the improvements in

ANTENNAE

described and claimed in the annexed specifications; that he does not know and does not believe that the same were ever known or used before his invention or discovery thereof; or patented or described in any printed publication in any country before his invention or discovery thereof or more than two years prior to this application; or patented in any country foreign to the United States on an application filed by himself or his legal representatives or assigns more than twelve months prior to this application; or in public use or on sale in the United States for more than two years prior to this application; and that no application for patent on said improvements has been filed by him or his representatives or assigns in any country foreign to the United States.

Philip Staats Carter

Sworn to and subscribed before me this

day of June 5, 1930

Ludwig A. Patterman
Notary Public

LUDWIG A. PATTERMAN
NOTARY PUBLIC
Suffolk County
Term Expires March 30, 1931

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Dept. 18

Fig. 1a

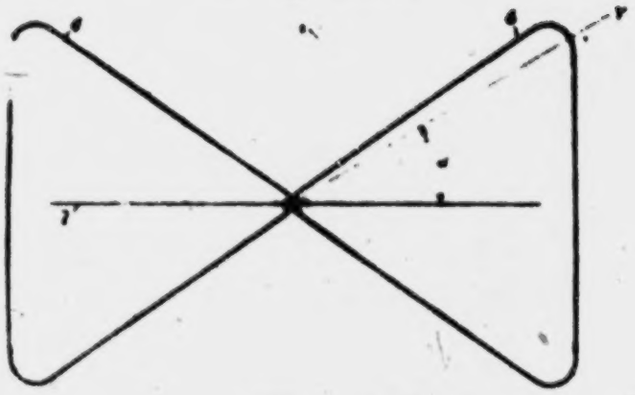


Fig. 1b

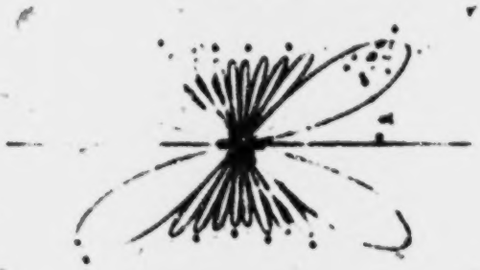


Fig. 2b

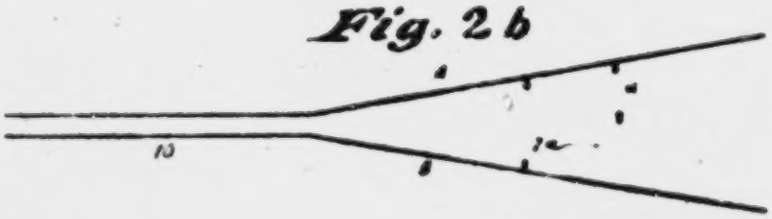


Fig. 2a



Fig. 2c



INVENTOR
P.S. CARTER
BY
ATTORNEY

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Fig. 3

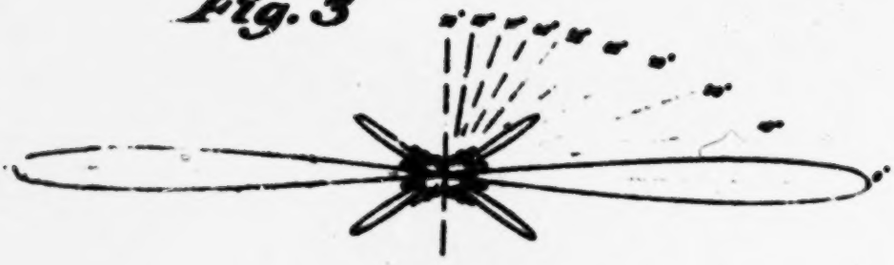


Fig. 4

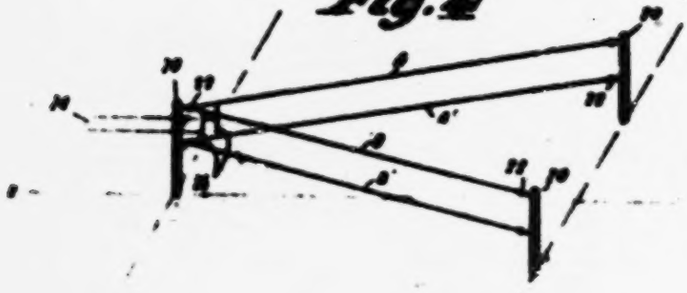


Fig. 5



Fig. 6

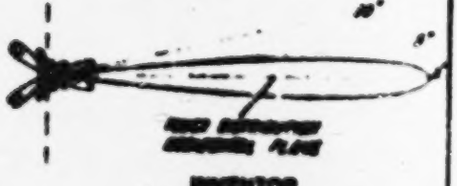
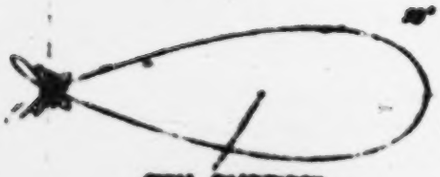


Fig. 7



INVENTOR
P. S. CARTER

BY M C C

ATTORNEY

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Fig. 8

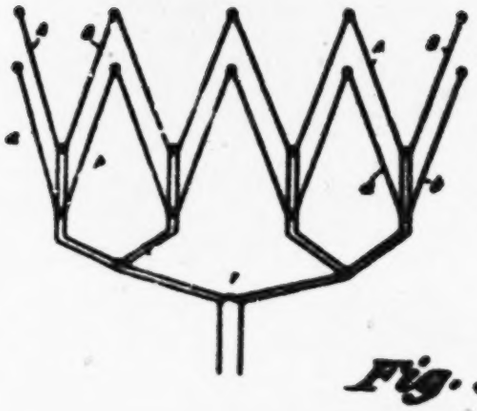


Fig. 10



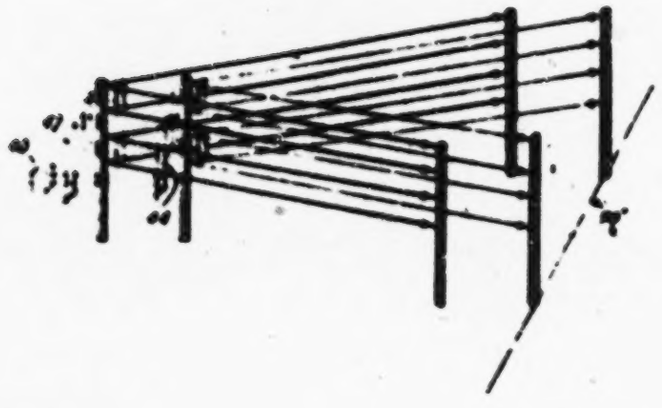
Fig. 10a



Fig. 9



Fig. 11



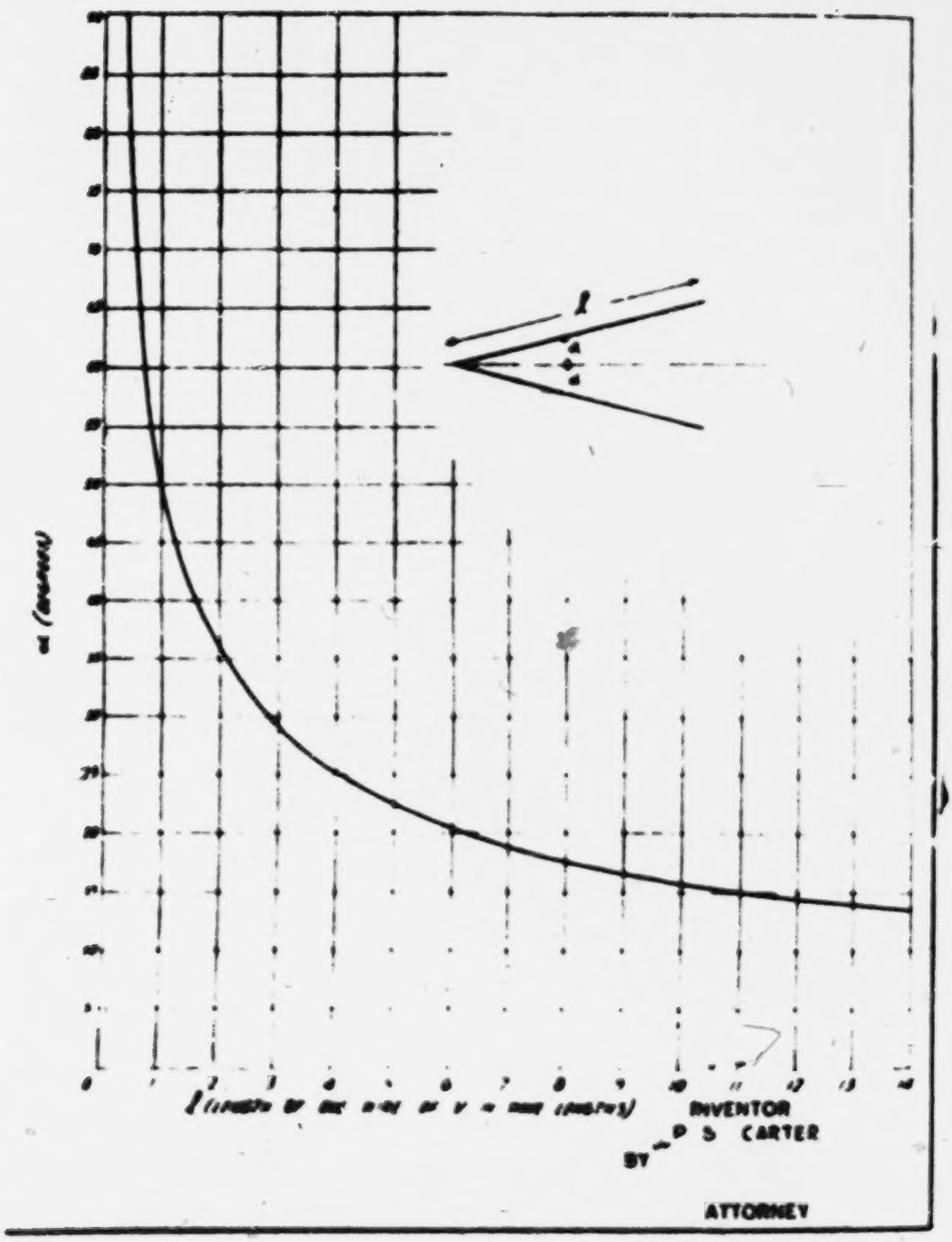
INVENTOR
P. S. CARTER

BY

ATTORNEY

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Fig. 12



4/5,467 - 18 - 25 11/55

Ex. 81 Form 240-Amend

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON March 3, 1931.

Paper No. 2

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson

Applicant: P. S. Carter

E. G. Grover,
C/o Radio Corp. of America,
233 Broadway,
New York, N. Y.

Ser. No. 460,447
Filed June 11, 1930
For Antenna

This application has been examined.

Record is made of:

Marconi	760,448	May 24, 1904	250-33
Garcia	795,762	Jul. 25, 1905	250-11
Alexanderson	1,401,873	Dec. 27, 1921	250-11x
British Patent	299,447 (2 sht.)	Feb. 28, 1929	250-33
British Patent	296,695 (5 sht. - sht. 2)	Jan. 31, 1929	250-11

All the claims are rejected as incomplete since, "angularly disposed" does not sufficiently define the structure. These claims should recite with respect to what the conductors are angularly disposed.

Claims 1-3, 5, 7, 9 and 10 are further rejected as functional since they recite functions not supported by the structure recited in the claims. The limitation, "having standing waves thereon" is not a proper limitation since it recites merely a condition of the apparatus in operation and no structural feature of the system.

Claims 1, 2 and 5 are rejected as reading directly on Garcia in every structural detail. The British patents also show antennae systems having a pair of angularly disposed conductors, as in Fig. 4, of British patent 299,447, the conductors 42 are angularly disposed with respect to the horizontal.

In claims 13-22, inclusive, the definitions of the symbols used in the mathematical expressions should be included in the claims, in order to distinctly point out the invention.

R 24

C. W. Jackson

Examiner

V 21

MAIL DIVISION
APR 23 31
U.S. PATENT OFF.

UNITED STATES PATENT OFFICE

APPLICATION OF: P. S. Carter

FOR: Antennae

SERIAL NO. 460,447 FILED: June 11, 1930

DIVISION: 51 ROOM: 240-Annex

New York, N. Y.
April 22, 1931

The Commissioner of Patents
Washington, D. C.

Sir:

On and after April 24, 1931 please address all communications intended for the attorney of record of the above entitled case to

Harry G. Grover
c/o Radio Corporation of America
570 Lexington Avenue
New York City, N. Y.

Respectfully,

P. S. CARTER.

H. G. Grover

by _____
Attorney

PAPER N 4
AMENDMENT a

SEP -2 31

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF: PHILIP S. CARTER
FOR: ANTENNAE
SERIAL NO: 470,467 FILED: JUNE 11, 1930
DIVISION: 51 ROOM: 240-ANNEX
LAST OFFICE ACTION: MARCH 3, 1931

SEP 4 - 1931

New York, N. Y. August 28, 1931.

COMMISSIONER OF PATENTS,
WASHINGTON, D.C.

SIR:

In response to the Office Action of March 3, 1931, kindly amend this case as follows:

Page 11, line 13, change "2" to the numeral 2.

Claim 1, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Line 3, after "long" insert at the operating frequency.

Same line, cancel "having" and insert in place thereof means for producing.

Claim 2, line 2, after "conductors" insert said conductors being angularly disposed with respect to each other.

Claim 3, line 3, change "having" to means for producing.

Claim 4, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 5, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 6, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 7, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 8, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 9, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 10, line 2, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Claim 11, line 2, after "conductors" insert , said conductors being angularly disposed with respect to each other.

Claim 12, line 2, after "conductors" insert , said conductors being angularly disposed with respect to each other.

Claim 13, line 1, after "conductors" and before the comma insert said conductors being angularly disposed with respect to each other.

Line 3, after "disposed" insert with respect to each other.

Last line, change the period to a comma and add n being the number of half wave lengths contained in each conductor.

Claim 14, line 3, after "disposed" insert with respect to each other.

Last line, change the period to a comma and add where n is the number of half wave lengths contained in each conductor.

Claim 15, line 3, after "disposed" insert with respect to each other.

Line 4, after "maximum," insert n being the number of half wave lengths contained in each conductor.

Same line after "and" insert a comma.

Claim 16, line 3, after "disposed" insert with respect to each other.

Line 4, after "maximum," insert n being the number of half wave lengths contained in each conductor.

Claim 17, line 3, after "disposed" insert with respect to each other.

Line 4, after "maximum," insert n being the number of half wave lengths contained in each conductor.

Claim 18, line 3, after "disposed" insert with respect to each other.

Line 4, after "maximum," insert n being the number of half wave lengths contained in each conductor.

Claim 19, line 2, after "disposed" insert with respect to each other.

Last line, change the period to a comma and add l being the length of the wire and λ the operating wave length in like units.

Claim 20, line 2, after "disposed" insert with respect to each other.

Last line, change the period to a comma and add l being the length of each wire and λ being the operating wave length in like units.

Claim 21, line 2, after "disposed" insert with respect to each other.

Last line, change the period to a comma and add l being the length of each wire and λ being the operating wave length in like units.

Claim 22, line 2, after "disposed" insert with respect to each other.

Last line change the period to a comma and add l being the length of each wire and λ being the operating wave length in like units.

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REMARKS:

Each of the claims have now been amended to state with particularity that the conductors are angularly disposed with respect to each other, and hence the rejection of incompleteness should be withdrawn.

It is respectfully submitted that claims 1, 2, 3, 5, 7, 9 and 10 are not functional. Each of claims 1, 2 and 3 call for means to produce standing waves on the radiators. The recitation of "means", of course, precludes these claims from being functional. Moreover, it is respectfully submitted that the quintessence of the present invention is the production of standing waves on the wires. Consequently, there should be no objection to this limitation in the claims inasmuch as the art clearly does not teach this feature. Similar remarks are applicable in connection with claims 7, 9 and 10 which require the parallel disposition of pairs of angularly disposed conductors whereby a beam of energy, propagated mainly in the direction of the bisector of the angle formed by the conductors, is concentrated. It is to be noted that here also these features are not to be found in the art of record and, consequently, upon reconsideration, it is thought that the formal objections to these claims should be withdrawn and the claims allowed.

It is respectfully submitted that claims 1, 2 and 3 are not anticipated by Garcia. It is to be noted that each of these claims requires conductors having a plurality of standing waves thereon; and, claim 2 in particular requires the standing waves on the conductors to be in phase opposition. In Garcia the conductors are all excited in phase as a simple inverted L type of antenna. There is no indication that a number of standing waves are produced upon each conductor of the antenna and still less does Garcia teach the fact that the waves on each conductor are to be in phase opposition.

In figures 1 and 3 of British patent 285,633, standing waves are not produced upon the linear conductors of the antennae systems but on the contrary, traveling waves are produced therein. Although figure 4 of the British patent requires the production of standing waves on the linear conductors, propagation is at right angles to the plane of the conductors and not as required by these claims on the bisector of the angle formed by the conductors. Similarly in figure 5 of British patent 290,647, the conductors 42 are parallel to each other and cannot be said to be angularly disposed whereby radiation occurs in the direction of the bisector of the angle formed by the conductors. Consequently, upon reconsideration, claims 1, 2 and 3 should be allowed over the British patents of record.

No art was cited against claims 13 to 22 inclusive, and, as they have been amended to include the explanation of the mathematical expressions used, should now be found allowable.

For the for going reasons allowance of the case in its present form is thought to be in order and is, therefore, respectfully requested.

Respectfully submitted,

PHILIP S. CARTER

BY H. B. Sweet
Attorney

HT:AU

PAPER NO 5
AMENDMENT B

UNITED STATES PATENT OFFICE

APPLICATION OF: P. S. CARTER

FOR: ANTENNAE

SERIAL NO.: 480,487 FILED: JUNE 11, 1930

DIVISION: 51 ROOM: 240-ANNEX

LAST OFFICE ACTION: MARCH 3, 1931.

NOV 18 1931

New York, N. Y., November 13, 1931.

COMMISSIONER OF PATENTS,

WASHINGTON, D. C.

DEAR SIR:

Please amend the above-entitled application as follows:

Add the following claims:

Thus. An antenna arrangement comprising a pair of diverging linear conductors angularly disposed with respect to each other, another pair of angularly disposed diverging conductors similar to said first mentioned pair and spaced apart from said first pair in a direction along the bisector of the angle of the conductors, both said pairs of angularly disposed conductors being arranged to form opposite angles of a four sided plane figure.

~~20~~. A diamond-shaped antenna arrangement comprising ~~two pairs of V-shaped antennae arranged to form a parallelogram~~

An antenna system comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of one-half wave lengths ~~long and~~ open-ended, another similar pair of angularly disposed linear conductors also a plurality of one-half wave lengths ~~long and~~ open-ended, both of said pairs being so arranged that the angles formed by each pair face one another, and means for exciting the radiators of each pair in phase opposition thereby standing waves of opposite instantaneous polarity are formed on the radiators.

1.

26. A directional transmitting antenna arrangement comprising two pairs of V-shaped antennas arranged to form a parallelogram, and means for exciting the radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

27. A directional antenna arrangement comprising two pairs of open-ended V-shaped antennas arranged in a horizontal plane such that the open ends of each pair point in opposite directions with respect to the other pair.

28. A directional antenna arrangement comprising two pairs of open-ended V-shaped antennas arranged such that the angles formed by the individual conductors of each pair antennas face each other and the open ends of each pair point in different directions.

29. A directional antenna arrangement comprising two pairs of V-shaped antennas arranged in such manner that the angles formed by the individual conductors of each pair face each other.

30. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of one-half wave lengths long, open-ended, and disposed in a plane at an angle from the horizontal, and means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.

26st. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other and lying in a plane at an angle to the horizontal, each substantially a plurality of one-half wave lengths long, means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of one-quarter wave lengths.

27st. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each substantially a plurality of one-half wave lengths long and open-ended, and disposed in a plane at an angle to the horizontal, means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators, and another pair of conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors by an odd number of one-quarter wave lengths.

28st. A directional transmitting antenna comprising a plurality of pairs of linear conductors angularly disposed with respect to each other, each substantially a plurality of one-half wave lengths long and open-ended, and disposed in a horizontal plane along the bisector of the angle of the conductors, means for exciting the two radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators of each pair, and means for feeding the successive pairs of radiators so that the currents

in the successive radiators of each pair differ in phase by an angle $2\pi S/\lambda$ where S is the spacing along the and λ the wave length.

29 ex. A directional transmitting antenna comprising a plurality of pairs of linear conductors, the conductors of each pair being angularly disposed with respect to each other, each conductor being of a length including substantially a plurality of one-half wave lengths and, said plurality of pairs being open-ended, disposed in a plane at an angle from the horizontal, said plane extending in the desired direction of transmission, means for exciting the two radiators of each pair in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators of each pair, and means for feeding the successive pairs of radiators so that the currents in the successive radiators of each pair differ in phase by an angle $2\pi S/\lambda$ where S is the spacing and λ the wave length.

30 ex. A broadside directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, another pair of angularly disposed linear conductors arranged adjacent and in the same plane with said first pair so that said two pairs are side by side and have their acute angles opening in the same direction, and means for producing standing waves thereon whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors of each pair for effecting beam concentration.

REMARKS.

Thirteen new claims 23 to 35 are herein being added to the application to more adequately protect applicant's invention.

New claims 23 to 29 are directed to a diamond-shaped antenna construction such as is illustrated in either Figure 13 or Figure 104, which particular arrangement is not to be found anywhere in the prior art so far as applicant is aware.

New claim 30 is somewhat similar in scope to claim 1 and includes a limitation not found therein.

Page Tightly Bound

New claims 31 and 32 are very similar in scope to claim 7 and read upon Figures 5, 9 and 11 of applicant's drawings.

New claims 33 and 34 are quite specific to an antenna construction wherein the successive radiators of each pair differ in phase by a particular formula.

New claim 35 is directed to the antenna construction illustrated in Figure 8 of the drawings. So far as applicant is aware this arrangement is not shown anywhere in the prior art and is thought to be clearly novel.

Since these new claims clearly distinguish from the disclosures of the references cited by the Examiner their allowance is respectfully requested.

Respectfully,

P. S. CARTER

By W. S. Grover
Attorney.

RB:BC

31

C. N. D.

No. 51 Room 2022 RSM:JB Paper No. 6

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON Mar. 7, 1932.

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
(Commissioner of Patents.)

Applicant P.S.Carter.

H.C.Beverage
c/o Radio Corp.of America,
570 Lexington Ave.,
New York, N. Y.

Ser. No. 460,487
Filed June 11,1930
For Antennae.

MAILED
MAR 7 1932

Responsive to amendments filed September 2, 1931 and November 17, 1931.

Additional record is made of:

Vonâree 1,827,864 Oct. 13, 1931 250/33.1

Claims 1, 3, 5, 7, 9 and 10 are again rejected as being functional since there is no structure to support the function of "having standing waves thereon" nor to support the statement in regard to the directional transmission. It appears that in order to support these functions it is necessary to state that the antennae are open-ended, and that means to excite them in phase opposition is provided. As pointed out in the last Office action, the limitation "having standing waves thereon" is merely a condition of the apparatus during use and not a structural limitation.

Claims 1 and 3 are further rejected as unpatentable over Carels, of record, or Vonâree, cited above, since they read substantially directly on either of these references in structure.

Claim 8 is rejected as being functional since the production of standing waves does not follow from the structure named.

Furthermore, it appears that this claim is drawn to substantially similar subject-matter as a copending application to Peterson assigned to the same assignee.

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It is not clear where applicant wishes the insertion made in claim 7, line 2, since no comma follows "conductors." Applicant should make it clear where he wishes this entered.

Claims 11, 12, 21 and 22 are rejected as being incomplete since the indefinite statements in regard to the spacing of the elements do not define a complete structure. Applicant has only shown a particular spacing that will satisfy his invention and should define the structure in the claims so as to point this out.

New claims 23-32, inclusive, and claim 35 are required to be cancelled as being drawn to an invention not previously claimed. Furthermore, claims 23-29 are drawn to the combination shown in Fig. 10 and 10a, which is a different invention from that covered by the claims and accordingly not allowable in the same application. Likewise, claim 35 is drawn to a different invention shown in Fig. 8 and could not be claimed in the same application as the allowed claims even if submitted with a supplemental oath.

Claims 4, 6, 8, 13-20, 33 and 34 appear to be allowable.

RMW

Examiner.

PAPER NO 7
AMENDMENT C'

MAIL DIVISION
AUG -8 32
UNITED STATES PATENT OFFICE

C

APPLICATION OF: P. S. CARTER
FOR: ANTENNAE
SERIAL NO.: 460,467 FILED: June 11, 1930
DIVISION: 81 ROOM: 5628
LAST OFFICE ACTION: March 7, 1932.

PATENT OFFICE
AUG 8 1932
DIV. 5 FILED

New York, N. Y., August 5, 1932.

COMMISSIONER OF PATENTS
WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of March 7, 1932, please amend the above-entitled application as follows:

C'

Claim 8, line 8, after "and" cancel "having standing waves" and substitute therefor --means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed--.

Claim 9, line 8, before "in" cancel "disposed";

line 8, after "and" cancel "having" and substitute therefor --means for producing--.

Claims 9 and 10, line 8, change "having" to --means for producing--.

Claim 11, line 8, after "spaced" insert --apart vertically--.

Claim 18, line 8, after "apart" insert --along the direction of the bisector of the angle formed by the conductors--;

line 8, after "a" insert --vertical--.

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Claim 21, line 3, after "in" insert --parallel--.

Claim 22, line 4, after "separated" insert --along the direction of the bisector of the angle formed by the conductors--;

line 6, after "plane" and before the comma insert --spaced apart from said first pairs--.

Claim 34, line 2, after "conductors" insert --, the conductors of each pair being--;

line 3, after "each" second occurrence insert --conductor being--;

line 4, cancel "and"/ second occurrence and substitute therefor --said plurality of pairs being--.

Claim 34, line 2, after "conductors" insert --, the conductors of each pair being--;

line 3, after "each" second occurrence insert --conductor being--;

line 4, cancel "and"/ second occurrence and substitute therefor --said plurality of pairs being--.

Claim 35, line 1, after "A" insert --broadside--;

last line, after "pair" and before the period insert --for effecting beam concentration--.

Add the following claim:

C2/ Reply

§136. A broadside directional antenna comprising a pair of linear conductors angularly disposed with respect to each other in a horizontal plane, another pair of angularly disposed linear conductors arranged adjacent and in the same plane with said pair so that said two pairs are side by side, said pairs being arranged to be excited in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon.

Cancel 3! 10-2-39

REMARKS.

The rejection of claims 1, 2, 5, 6, 7, 9 and 10 as being functional is not understood inasmuch as claims 1 and 5 have previously been amended to recite "means for producing standing waves", a limitation to structure which clearly supports the statement in the claims in regard to directional transmission. Claims 6, 7, 9 and 10 have now been similarly amended to overcome the Examiner's rejection.

Apparently, the manner of producing standing waves on antennae is not clearly understood by the Examiner, otherwise he would not have made the statement that it is necessary for the antennae to be open-ended to produce standing waves. It is submitted that standing waves may be produced on antennae whether they are open-ended or even closed by a short circuit. One method of obtaining horizontal standing waves as long as the operating wave length on elevated conductors is described in Alexanderson patent 1,300,167 of November 25, 1919, to which the Examiner's attention is invited. To produce standing waves it is merely necessary that the termination of the antennae be such that the currents in the wires are reflected from the ends thereof in proper phase relation. Two requirements to be followed are that the attenuation of the wires should not be so great that

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the currents are dissipated therein before they reach the ends of the wires, and that the termination should not have a resistance equal to the surge impedance of the wires so as to cause traveling waves. In order to effect the standing wave phenomena the current and the voltage at the reflecting terminal of the line, where the wires are open-ended or short-circuited, must lead or lag with respect to one another. In view of this explanation it will be seen that applicant need not unduly limit his invention to open-ended conductors when he is clearly entitled to broad claims consistent with the state of the art omitting this unnecessary limitation. It is urged that the structure disclosed in these claims is sufficiently adequate to produce an operative device in accordance with applicant's teachings, and that the Examiner should not deny applicant a broad claim to which he is clearly entitled as a protection for his invention on the ground that because it is broad it is functional. It is suggested that the amendments to these claims, which now call for "means for producing standing waves" or some such equivalent, provide sufficient structure to support any and all statements appearing therein and render the claims clear and concise.

The rejection of claims 1 and 8 as being ungatentable over Garcia patent 786,768, July 25, 1905, or Vendres patent 1,827,864, October 13, 1931, is clearly not well taken since both of these claims are limited to "directional antennae" and to "means for producing standing waves" to effect applicant's purpose, features not shown, taught or even suggested in the disclosures of the references. Further, claims 1 and 8 call for conductors a plurality of half wave lengths long, a limitation not even mentioned in the cited art. In this connection, it should be noted that the Garcia patent was filed in 1901 at a time when wave lengths of the

conductor of one-half wave length would be equivalent to, let us say, 1000 meters or over 3000 feet, a distance more than half a mile which is a length greater than any antenna ever built for those waves. From this it will be seen that the claims additionally distinguish over the Garcia patent by the recitation of the specific length of the conductors. Further, claim 3 calls for the conductors disposed in a horizontal plane, a feature of which the VenArco patent is entirely silent. In fact, to dispose the conductors in a horizontal plane would be to proceed directly contrary to VenArco's teachings who specifically states on page 1, lines 32 to 34 of the patent that it is his intention to dispose a series of linear oscillaters with varying altitude and azimuthal angles. The disclosures of both references are directed to antennae adapted to radiate uniformly in all directions and are clearly irrelevant. With all due respect to the Examiner's opinion, they cannot possibly be used as anticipations without violating their expressed teachings and without distorting and reading into the specifications of the disclosures a mode of operation of which they are entirely silent and which proceeds directly contrary to their inventions.

The reasons mentioned above in connection with claims 1, 5, 6, 7, 9 and 10 apply with equal force and effect to claim 8. The rejection of this claim is clearly inconsistent with the allowance of claim 4 which is of almost identical scope with claim 8 except for the limitation "disposed in a horizontal plane" appearing in claim 4. Either claim 8 is allowable for the same reason that claim 4 was allowed or else claim 4 should be rejected on the same ground of functionality as was claim 8. However, since the Examiner's position is clearly untenable this contention will not be pursued further as the allowance of claim 8 is believed to be clearly in order.

With reference to the statement that claim 2 is drawn to substantially similar subject matter as a copending application of Peterson assigned to the same assignee, it is submitted that applicant has diligently searched through the Peterson applications and has failed to find any disclosure of angularly disposed linear conductors, open-ended, and having means for exciting the radiators in phase opposition to obtain standing waves of opposite instantaneous polarity thereon. Since Peterson's applications are numerous, applicant's attorney will appreciate the citation of the serial number which the Examiner has in mind in order to clearly point out the distinguishing characteristics thereover.

Applicant regrets that the amendment to claim 7, line 2, appearing in his previous amendatory paper of August 28, 1931 was not clear and submits that the insertion should be made immediately after the word "conductors" appearing in the second line of this claim.

Claims 11, 18, 21 and 28 have been amended and are now thought to be definite and exact in regard to the spacing of the elements. These claims are now thought to be allowable for the same reason that claims 13 to 20 have been allowed.

Claims 33 and 34, which have been allowed, have been amended to render them more difinite. It is submitted that the scope of the claims has not been changed one iota and it is requested that these claims be permitted to remain allowed.

The rejection of claims 23 to 32 and 35 as being drawn to invention not previously claimed is not understood since applicant has at all times submitted claims generic to all species disclosed in the drawing and is clearly entitled to claims covering three of the species. It is submitted that original claims 1 to 4, 13 and 19 are generic to all species. None of the original claims heretofore presented are specific to any one particular

species. For example, claims 5 to 9, 15, 16 and 20 are considered to be generic to Figures 5, 8, 9 and 11. Further, original claims 9, 15, 16 and 20 are also considered to be generic to Figures 13 and 13A. For this reason, it is firmly believed that applicant is clearly entitled to present claims to other species which he has all the time been claiming generically. If the Examiner persists in the requirement that these claims be cancelled, he is requested to point out authority for his action since it is considered to be clearly unwarranted and a departure from well established practice. An action on the merits of these claims is respectfully requested.

New claim 36 is of scope similar to claim 35 and is directed to the arrangement shown in applicant's Figure 8. This claim distinguishes over the art for the same reasons heretofore pointed out in connection with claim 35.

Claims 4, 6, 8, 13 to 20, 35 and 34 have been indicated as being allowable.

Reconsideration of all claims in their present form and their allowance, together with newly presented claim 36, are respectfully requested.

Respectfully submitted,

P. S. CARTER

By H. B. Glover
Attorney.

CHB:BG

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C. K. D.

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No. 51 Room 5625

Address only "The Commissioner of Patents, Washington, D. C." and not any official by name

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON December 8, 1932.

Paper No. 8

MAILED

DEC 9 1932

Please find below a communication from the EXAMINER in charge of this application.

Thomas E. Robertson
Commissioner of Patents.

H. G. Grover,
C/o Radio Corp. of America,
990 Lexington Avenue,
New York, N. Y.

Applicant: P. S. Carter

Ser. No. 460,467
Filed June 11, 1930
For Antennae

Responsive to amendment filed August 4, 1932.

Claims 1 and 3 are again rejected as unpatentable over Carsis or Von Arco since they read substantially directly on these references. The sole distinction applicant points out is recited in the functional descriptive word "directional". Obviously, the transmitters in either of these patents form means for producing standing waves on the antennae.

The requirement that claims 23-32 be cancelled as being drawn to a different invention than that previously claimed is repeated. It is pointed out that no claim generic to the several species illustrated is included in the application. Claims 1-4, 13, and 19 read on a single antenna unit such as is used in all the species but they accordingly are drawn to a sub-combination and not to a generic form of the invention. Claims 5-8, 15, 16 and 20 are generic only to Figs. 8, and 9, but also read on a horizontal unit of the antennae shown in Figs. 8 and 11. Claims 9, 10, 17, 18 and 21 read specifically on Fig. 4 only but may also be a unit in the arrays of Figs. 6 and 11.

Claims 11, 12 and 22 are specific to the embodiment illustrated in Figs. 8 and 11.

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Claims 23-29 submitted in the amendment filed November 17, 1931 read only on Figs. 10 and 10^a and are not supported by any generic claims.

Claims 33 and 34 read on Fig. 9 but also are generic to the unit used in Figs. 5 and 11.

Claims 35 and 36 read only on Fig. 6 and are supported by no generic claims.

Since no generic claim is found in the application and since applicant elected in filing the original application to prosecute claims specific to Figs. 5 and 11, claims 23-29 and claims 35 and 36 drawn to Figs. 10 and 10^a and Fig. 8, respectively, are required to be cancelled.

See preceding page

Claims 30-32 are rejected as not being supported by sufficient disclosure since no illustration of the antennae inclined to the horizontal is included.

Claims 2, and 4-22 appear to be allowable.

D. O. Dawson

Examiner

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PAPER NO 2
AMENDMENT

UNITED STATES PATENT OFFICE

APPLICATION OF: P. S. CARTER

FOR: ANTENNAE

SERIAL NO.: 463,467 FILED: June 11, 1930

DIVISION: 51 ROOM: 5628

LAST OFFICE ACTION: December 8, 1932.

PATENT OFFICE
MAY 10 1933

New York, N. Y., May 6, 1933.

COMMISSIONER OF PATENTS

WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of December 8, 1932, please amend the above-entitled application as follows:

Page 8, line 8, singularize "systems".

Cancel claim 1 and rewrite same as follows:

37. A directional antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of said conductors being substantially a plurality of half wave lengths long at the operating frequency, and means for energizing said conductors out of phase with respect to each other whereby radiant action is predominantly along the direction of the bisector of the angle formed by the conductors.

Cancel claim 3 and rewrite same as follows:

38. A directional antenna comprising a pair of linear conductors in a horizontal plane angularly disposed with respect to each other, each substantially a plurality of half wave lengths long, and means for energizing said conductors out of phase with respect to each other whereby radiant action of the antenna is predominantly along the direction of the bisector of the angle formed by the conductors.

1. [illegible] 43

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Claims 5, 7 and 9, line 3, after "long" insert a comma and cancel "and".

Claim 10, line 3, after "long" insert a comma and cancel "and"; last line, singularise "planes" and "pairs".

REMARKS.

The specification has been amended in order to overcome an obvious typographical error.

Claims 1 and 3 have been cancelled and rewritten as new claims 37 and 38 in order to more clearly distinguish over the Garcia and Von Arco citations. As now written these claims call for, in addition to the limitations previously pointed out, means for energizing the angularly disposed conductors out of phase with respect to each other in order to obtain the desired radiant action. The systems of the references, it should be noted, utilize conductors which are all excited in phase, just like the simple inverted "L" type of antenna. For this reason these claims are now considered to be clearly allowable, early notice of which is respectfully requested.

Claims 5, 7, 9 and 10, which have been indicated as being allowable, have been amended merely in the interest of clarity. Since the scope of these claims has not been changed one iota no objection should be made to these minor changes and for this reason it is requested that they remain allowed.

Claims 2 and 4 to 22 inclusive stand allowed.

Claims 23 and 24 have previously been allowed in the Office action dated March 7, 1932, and since no objection has been raised by the Examiner in his last Office action it is assumed that these claims are also allowable.

The requirement that claims 25 to 29 be cancelled on the ground that there is no generic claim in the application is considered to be ill founded and its reconsideration is respectfully requested. It is submitted that claims 9, 15 and 16 are generic in this application not only to Figures 8 and 11, but

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also to Figures 10 and 10A. More specifically, these claims recite that there are two similar pairs of conductors spaced apart from each other in a direction along the bisector of the angle. These claims were specially drafted and worded in this particular manner in order to generically cover the specific arrangements of Figures 10 and 10A and for this reason applicant is clearly entitled at this time to draft other claims which are limited to these last two figures. It is respectfully advised that the Examiner should not be misled by the mere term "similar" which, in its ordinary dictionary meaning, expresses the idea of bearing a resemblance to something else, but not being completely identical. (Note Funk & Wagnalls dictionary) Apparently the Examiner has taken this expression "similar" to mean that the pairs of wires must be parallel to each other. This is not so since applicant has specifically drafted claims employing the term "parallel" wherever he has meant to designate parallel pairs of wires. In view of the foregoing, it is thought that the Examiner will readily see that he was in error in his interpretation of these claims and that he will withdraw his objection to claims 28 to 29, an action on the merits of which is respectfully requested.

As regards claims 30 to 32, which are limited to an antenna inclined to the horizontal, it is not agreed that these claims are not supported by the disclosure of the specification inasmuch as the last paragraph on page 12 adequately describes such an arrangement. Moreover, the drawings adequately illustrate an antenna in a plane which may be considered either to be horizontal or at an angle inclined to the horizon. It should be noted that the drawings do not show any horizontal reference and for this reason they are illustrative of all antennas which have their planes either horizontal or at an angle inclined to the horizon. In this connection applicant submits that the

rejection of these claims is extremely technical since the invention is adequately described and illustrated and it would not aid in explaining the invention further to illustrate antennae both horizontal and at an angle with respect to the horizon. It is noted that claim 34 which stands allowed is similarly limited to antennae at an angle to the horizon. For these reasons it is thought that the Examiner will readily appreciate applicant's position and will withdraw his rejection of these claims.

The Examiner's contention that claims 35 and 36 read only on Figure 8, it is respectfully submitted, is considered to be ill founded since claims 1 to 4, 18 and 19 are believed to be generic to all of the claims and not to be of the subcombination type as considered by the Examiner. In fact, all claims other than those immediately mentioned above are subcombination claims since they are specific to one or more figures, whereas claims 1 to 4, 18 and 19 are generic to all figures.

In view of the foregoing, it is thought that all claims now present in this application are allowable and, therefore, allowance is earnestly requested so that this application may soon pass for issue.

Respectfully submitted,

P. S. CARTER

By J. R. Brower
Attorney.

CRB:BC

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C. N. D.

5634

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July 28, 1933.

P. S. Carter,
No. 460,467.

Examiner, Division 51:

The requirement of division in this case was restated in the office letter of December 8, 1932. It was held there that Claims 1-4, 13, 19, read on a single antenna unit. This is correct but they are not limited to a single antenna unit. The words of these claims include "comprising" and are directed to an antenna "comprising," which word is not an exclusive word. Claims 2, 4, 13, 19, read it is thought upon all the figures in the case, viz., Figures 2, 4, 5, 11, 8, 9, 10. Similarly it must be held that the form which reads upon Figure 4 also reads upon Figures 5 and 11, and since Figure 8 is described as being made of units similar to Figure 5 those claims which read on Figure 5 also read upon Figure 8.

There are certain claims, as 23-29, which are limited to Figure 10. Other claims, as 35, 36, are limited to the broadside arrangement of Figure 8. These constitute distinct species and election between them is necessary if no generic

460,467 47 R+

claims are found which cover them.

Analysis of the claims indicates that Claims 2, 4, 13, 14, 19, 30, 37, 38, read upon Figures 2, 4, 5, 11, 8, 9, 10, and are generic; that Claims 5-8, 15, 16, 20, 31, 32, 33, read on Figures 5, 11, 8, 9; that Claims 9, 10, 17, 18, 21, read upon Figures 4, 5, 8, 11; that Claims 11, 12, 22, read upon Figures 5, 8, 11; that Claim 34 reads on all figures except Figure 2.

Election between Claims 23-29, upon the one hand, and Claims 35, 36, upon the other, is approved if none of the claims 2, 4, 13, 14, 19, 30, 37, 38, which are generic to these two forms, are found allowable. Otherwise election does not appear to be necessary, nor if applicant has generic claims is it thought that he should be required to cancel the claims reading upon Figure 10.

There is another limb in the case between the words "horizontal", Claims 4, 8, 12, 33, 36, 38, and "inclined to the horizontal," in Claims 30, 31, 32, 34. If the generic claims are found allowable, this distinction would constitute a third species, otherwise election should be made in this instance also.

The examiner has rejected the claims "inclined" as comprising new matter and the paragraph above need be taken into consideration only if that rejection is withdrawn.

C. H. Duncan

CHD:MS Examiner of Classification.

4 - 7 48 #19

Ex. GJ Room 2022 DEPARTMENT OF COMMERCE Paper No. 10
UNITED STATES PATENT OFFICE
WASHINGTON August 8, 1933.

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents.

F. G. Grover,
C/o Radio Corp. of America,
570 Lexington Avenue,
New York, N. Y.

Applicant: R. S. Carter
Ser. No. 460,467
Filed June 11, 1930
For Antennae

MAILED
AUG 8 1933

Responsive to amendment filed May 9, 1933.

It is noted that claims 3, 4, 13, 14, 19, 37 and 38 are drawn to substantially the same invention as is covered by the claims of an allowed application of Lindenblad assigned to the same assignee. Accordingly, these claims are rejected on the ground of double patenting. Claims 13, 14 and 19 give specific angles of separation, all of which are merely variations within the scope of claims allowed in the above-mentioned application and are not considered patentably distinct therefrom.

Claim 30, 31, 32 and 34 are not properly illustrated since no showing in the drawing of the conductors extending at an angle to the horizontal is made. Since this feature is claimed particularly it must be illustrated.

The examiner of classification held in substance that claims 3, 4, 13, 14, 19, 30, 37 and 38 are generic and if none of these claims are found allowable election between 22-29 and, 33 and 35 is approved.

Accordingly, since no generic claim is found allowable the requirement of election of species is held

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PAPER NO. 2, S. N. 466,467

in abeyance pending presentation of an allowable generic claim. No action on the merits of claims 23-29, 33 and 34 is made at this time since applicant has made no election of species.

Claims 5-12, 15-18, 20-22 and 35 appear to be allowable.

P'M

Respectfully,

MAIL DIV.
JAN 1934
UNITED STATES PATENT OFFICE

APPLICATION OF: P. S. CARTER

FOR: AERIAL

SERIAL NO.: 460,467 FILED: June 11, 1930

DIVISION: 21 ROOM: 5428

LAST OFFICE ACTION: August 8, 1933.

PATENT OFFICE
JAN 18 1934
DIV. 21 FILE

New York, N. Y., January 13, 1934.

COMMISSIONER OF PATENTS

WASHINGTON, D. C.

DEAR SIR:

In response to the Office action of August 8, 1933, please amend the above-entitled application by cancelling claims 2, 4, 37 and 38.

REMARKS

Claims 2, 4, 37 and 38 are being cancelled without prejudice.

It is not agreed that the Examiner is correct in his rejection of claims 13, 14 and 19 on the claims of an allowed application now issued to one Lindenblad assigned to the same assignee. It is assumed that the Examiner has reference to United States patent 1,927,522, granted September 19, 1933, and it is to this particular patent that applicant directs his accompanying remarks.

It is admitted that the Lindenblad patent is broad and dominates the present arrangement in some respects, but is is submitted the patent does not show the relation between the angle and the exact length of antenna as applicant teaches. A careful review will show that applicant's concept does not appear in Lindenblad's disclosure and for this reason applicant is clearly entitled to claims 13,14 and 19 as protection for his invention.

Claim 14 recites a formula which is theoretically exact and claim 15 one which is empirical. Favorable reconsideration and withdrawal of the rejection of these three claims are respectfully requested.

The rejection of claims 30, 31, 32 and 34 as not being properly illustrated because the feature "at an angle to the horizontal" is claimed particularly, has been noted. Applicant repeats his remarks hereinbefore stated in his previous amendatory paper of May 6, 1933, that the drawings adequately illustrate an antenna in a plane which may be considered either to be horizontal or at an angle inclined to the horizon, particularly so since the drawings do not show any horizontal reference and for this reason are illustrative of all antennae which have their planes either horizontal or at an angle inclined to the horizon. It is submitted that the invention is adequately described and illustrated and that any new drawing would not aid in understanding the invention further, but would, rather, clutter up the drawings and would detract from the clearness of the invention. However, if the Examiner persists applicant will be glad to present an additional showing of the antenna at an angle to the horizon, but requests that such requirement be waived for the present until these claims are allowed. Since this is a mere formality, it is thought that no objection will be raised to such a request since a showing will be forthcoming upon allowance of these claims. Inasmuch as claim 34 was previously allowed and subsequently rejected on this ground of insufficient showing it is thought that the other claims are clearly allowable with it and such action is earnestly requested.

The requirement for election between claims 28-29 and 35-36 pending allowance of a generic claim has been noted and applicant hereby elects to prosecute claims 28 to 29 pending allowance of a generic claim, such as 13, 14, 19 and 20, at which time he reserves the right to prosecute further claims 35 and 36.

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Since the generic claims are considered to be clearly allowable, it is thought that an allowance of all claims now present in this application should be forthcoming, which is requested.

Claims 5 to 12, 15 to 18, 20 to 22 and 35 stand allowed.

This application is now believed to be in condition for allowance and notice of such allowance is requested so that this application may soon pass for issue.

Respectfully submitted,

P. S. CARTER

By H. B. Brown

Attorney.

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UNITED STATES PATENT OFFICE

APPLICATION OF: P. S. Carter

FOR: Antennae

SERIAL NO: 460,487 FILED: June 11, 1930

DIVISION: 51 ROOM: 5628

LAST OFFICE ACTION: August 8, 1933

PATENT OFFICE
FEB 12 1934
DIV 51 FILED

February 9, 1934

Hon. Commissioner of Patents
Washington, D. C.

Sir:

Please amend the above entitled application by adding the following claims:

5240. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths long and being open-ended, a transmission line, a pair of vertical connections extending from said pair of conductors to said transmission line, and means in circuit with said transmission line for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors, another pair of conductors substantially similar and parallel to said first mentioned pair and spaced therefrom in a direction along the bisector of the angle of the conductors, and a pair of vertical connections in circuit with said last pair of conductors, and joining said last pair with said transmission line.

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39. A directional transmitting antenna comprising a pair of linear conductors angularly disposed with respect to each other, each of a length including substantially a plurality of half wave lengths long and open-ended, a transmission line, a pair of vertical connections extending from said pair of conductors to said transmission line, and means in circuit with said transmission line for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors, another pair of conductors substantially similar and parallel to said first mentioned pair and spaced therefrom in a direction along the bisector of the angle of the conductors, and a pair of vertical connections in circuit with said last pair of conductors, said two pairs of vertical connections being joined together by a pair of horizontal conductors.

REMARKS

Newly added claims 39 and 40 are being added to more adequately protect the present invention. These claims are drawn somewhat along the lines of allowed claim 6 and include, except for the omission of an expression in claim 6, more specific limitations than this allowed claim.

Respectfully submitted,

P. S. CARTER

by H. G. Brown
Attorney

CHB:RH

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE

EFH:ECG April 11, 1934

Please find below a communication from the EXAMINER in charge of this application.

APR. 11 1934

Applicant: R. S. Carter

d. C. Sawyer,
c/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N.Y.

Ser. No. 460,687
Filed June 11, 1930
For Antennae

Responsive to amendments filed January 13 and February 10, 1934

Additional record is made of:

Lindenblad 1,987,822 Sept. 19, 1933 250-33.1

Claims 13, 14 and 19 are again rejected as unpatentable over the Lindenblad patent cited above assigned to the same assignee. These claims differ from this reference only in the recitation of a particular specific design of the antenna conductors clearly within the scope of the claims of that patent. If applicant persists in claiming this specific arrangement it is requested that some authority in support thereof be cited.

It further appears, that in even such a claim can be established, the claims should include therein a statement of the improvement in result as well as the specific design limitations.

Since applicant's presentation of claims in the original application constituted an election of species, which as pointed out embraces the form illustrated in Figs. 10 and 10a election of such species can not be required. However, since it appears that in accordance with the ruling of the Examiner of Classification claims reading on Fig. 5 read also on Fig. 8 action on the merits of those claims is made in this action.

While no complete action is made on claims 23-29 at this time it is pointed out that in claims 24 and 26-29 applicant calls for two pair of V-shaped antennas, placed so as to form a parallelogram. It appears that this structure is erroneous since two pair of such antennas would be four V-shaped elements and applicant has not disclosed such a structure. Also, the term "face each other" as used in claims 26, 28 and 29 does not properly define the structure and that the proper space relation of the antenna elements is not fully defined in certain of the claims.

Claim 30 is rejected as not being patentably distinct from Lindenblad cited above. In that reference it is clearly pointed out that the antenna may be in a vertical plane, which construction clearly meets the qualification "disposed in a plane at an angle from the horizontal".

Claims 31, 33 and 34 are rejected as being indefinite in the term 'disposed in a plane at an angle to the horizontal". In the specification applicant defines this plane as inclined to the horizontal in the desired direction of transmission. It appears that this is the only such angular system disclosed and accordingly should be so claimed.

Claims 35 and 36 are rejected as being incomplete since they do not define the position of the units definitely. It appears that the units arranged "side by side" must also have their angles opening in the same direction to completely define the structure.

Claims 8-12, 15-18, 20-22, 25, 39 and 40 appear to be allowable.

In view of the age and status of this application, applicant is urged to reply promptly placing this application in condition for final adjudication.

RM

Examiner

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MAY 3 34

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF	PHILIP S. CARTER
FOR	ANTENNAE
SERIAL NO. 460,487	FILED JUNE 11, 1930
DIVISION 51	ROOM 5628
LAST OFFICE ACTION	APRIL 11, 1934

PATENT OFFICE
MAY 4 1934
DIV. OF FILES

New York, New York May 2, 1934

HON. COMMISSIONER OF PATENTS
WASHINGTON, D. C.

SIR:

In response to Office Action of April 11, 1934, please amend as follows:

Cancel page 1 and rewrite same as follows:

This invention relates to directive antenna systems, and has for its primary object to provide a simplified and highly efficient antenna system utilizing standing wave phenomena.

It is known that when a wire having a length greater than the operating wave length is excited in such manner that standing waves are produced thereon, radiation will occur principally in the direction of symmetrical cones having their apices at the center of the wire. Such is the case with a wire having a length equal to a plurality of one-half wave lengths at the operating frequency. The radiation pattern produced in such instance appears, in cross section, in the form of symmetrical cones about the wire. The present invention, which makes use of these phenomena, in its most simple aspect employs a pair of coaxial-ended wires energized to have standing waves throughout the length of the wires, the wires having such angular relation with respect to each other as

to obtain a highly directional, efficient and simple antenna system. It is proposed to place these wires at an angle with respect to each other so that principal radiation takes place along the bisector of the angle. This angle, in general, corresponds to the angle of the principal cone of radiation of one of the conductors.

Another object of the invention is to disclose the angle for the best directional propagation for open-ended wires of any finite length, preferably longer than the operating wave length, having standing waves thereon and arranged in the manner proposed.

Since a pair of wires of the type above described having standing waves thereon which are angularly disposed with respect to each other, radiate equally well in two directions, i.e., towards the diverging ends of the wires and towards the converging ends of the wires, such an arrangement is known as a bidirectional system.

Page 2, line 1, after "invention" insert --therefore--;
line 2, change "is" to --may preferably be--;
line 7, change the semi-colon to a comma;
line 9, after "is" insert --a--;
line 11, change "To" to --A still further object is to--; same line, cancel the comma after "plane";
line 12, before "usually" insert --(which is--;
line 13, after "planes" change the comma to a closed parenthetical mark as --)--.

Page 7, line 14, cancel "is a further object of the present invention; and," and substitute --end--.

line 19, cancel "accordingly" and substitute --In order to further--;

line 20, change "hereinbefore" to --heretofore--;

Cancel lines 15 and 20 and substitute --Other objects and features will appear in the subsequent detailed description referring to the various embodiments of the invention disclosed in the accompanying drawings.--

Page 8, rewrite the first sentence as follows:

--In general, as shown in Figure 1, there are two principal hollow cores 4, 6 of radiation about a wire such as indicated by the reference character 2, which is long relative to the working wave length.--

line 4, after "6" insert a comma;

line 5, change "wire, at" to --wire having--;

line 10, change "wire," to --wire which is--;

same line, change "having" to --and has--;

line 12, before "four" insert --there are five cores in each quadrant--;

line 13, cancel "there are five cores in each quadrant,--;

line 15, change "direction" to --directions--;

line 16, change "each cor ig" to --alternate cors are--;

line 23, after "used" insert --each of--;

line 24, change "occur mainly" to --mainly occur--.

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Page 6, line 4, after "wire" insert a comma;

line 11, change "lenred" to --letter--;

line 7 from the bottom, before "the wire" insert --at which--; same line, cancel "at";

lines 5 and 6 from the bottom, cancel "The obtaining of" and insert --Obviously--;

line 4 from the bottom, change "obviously, be readily" to --readily be--;

Page 7, lines 1 and 2, change the location of "is sufficiently accurate" to before --where l--;

line 19, insert a comma after "sub";

line 21, change "for," to --since--;

line 25, cancel "in phase opposition" and substitute --obtained from line 10--;

line 26, before the period insert --whereby the conductors are excited in phase opposition--;

lines 16 and 27, cancel "such that there is no reflection along transmission line 10";

last line, cancel the period and add:

-- in order that there may be no reflection along transmission line 10.--.

Page 4, line 5, after "loop" insert --itself--;

line 6, change "or" to --to be--;

line 9, before "line" insert --transmission--;

rewrite lines 16-18, inclusive, as follows:

—It should be noted that energy should always be fed to the radiators A,B out of phase, otherwise at a distant point P along the axis X-X there would be radiation cancellation instead of addition. It is also to be distinctly understood that the unit so far described, is not only useful for radiation purposes in a transmitting arrangement but may be—

Page 8, line 28, cancel "Moreover, it should be clearly" to --It is to be further--;

line 34, change "length whatsoever" to --desired length--;

line 38, before "length" insert --particular--;

line 39, change "but," to --although--;

lines 39 and 40, cancel the comma;

line 40, before "due" insert --herein--;

line 41, cancel the second comma.

Page 9, line 3, change "Figure," to --In Figure 4,--;

line 10, cancel "and";

second paragraph, lines 3-4, rewrite the second sentence to read as follows:

--which respect to wires which are several wave lengths long, it should be noted that vertical radiation is either zero or practically very small.--;

line 5, (second paragraph) change "specifically, it" to --More specifically, vertical radiation--.

Page 10, rewrite the first paragraph as follows:

--In order to obtain a unidirectional radiation characteristic, pairs of parallel units such as shown in Figures 3a, 3b and 4a are to be spaced apart a distance along the axis X-X, which in effect is the bisector of the angle formed by each pair of wires in each unit. This distance may, in the preferred arrangement, be equal to an odd number of quarter wave lengths.--

line 18, after "with" insert --respect to--;

line 28, after "units" insert --, there are no wide--;

lines 28 and 29, cancel "are provided," and substitute --which are--.

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Page 11, line 1, after "desired" insert a comma;

line 4, change "broadside and" to

--broadside with other units, and the several units--;

line 5, after "plan" insert --view--;

line 6, change "Through" to --By means of--;

line 7, insert a comma after "lines" and after "T";

Rewrite claims 13 and 14 as follows:

14.- An antenna system comprising a pair of linear conductors, said conductors being angularly disposed with respect to each other, each substantially an odd number of half wave lengths long and angularly disposed with respect to each other at an angle substantially equal to the angle for which the field strength at a distant point lying in the direction of the bisector is a maximum, said field strength being proportional to $\frac{\cos\left(n\pi \frac{\pi}{2} \cos\theta\right)}{\sin\theta}$ where n is the number of half wave lengths contained in each conductor and θ is the half angle between the wires, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.

Cl. 10 Over

10. An antenna comprising a pair of linear conductors each substantially an even number of half wave lengths long and disposed with respect to each other at an angle substantially equal to the angle for which the field strength at a distant point lying in the direction of the bisector is a maximum, said field strength being proportional to

$$\frac{\sin\left(n\pi\cos\frac{\theta}{2}\right)}{\sin\theta}$$

where n is the number of half wave lengths contained in said conductor and θ is the half angle between the wires, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.

Claim 19, line 8, after the insertion add: --, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length.--.

Claim 24, line 2, change "two pairs" to --a pair--.

Claim 25, line 6, before "angles" insert: --open ends of one pair point in a substantially opposite direction with respect to the open ends of the other pair and the acute--

line 7, change "each pair" to --said pairs--.

Claim 26, line 2, change "two pairs" to --a pair--.

Claim 28 and 29, lines 1 and 2 of each claim, change "two pairs" to --a pair--; line 3 of each claim, change "angles" to --acute angle--.

Cancel claim 30.

Claim 31, line 5, cancel "each" and substitute:
--said plane extending in the desired direction of transmission, each conductor being--;

Claim 32, line 5, after the comma insert --said plane extending in the desired direction of transmission,--

Claim 33, last line, after "spacing" insert --along the bisector--.

Claim 34, line 5, after the comma insert:
--said plane extending in the desired direction of transmission,--.

Claims 35 and 36, line 5 of each claim, after "side" and before the comma insert --and have their angles opening in the same direction--.

Claim 35, line 7, change "bisector" to --bisectors--.

Add the following claims.

---

37. An antenna arrangement comprising a pair of conductors each of a length exceeding several half wave lengths long at the operating frequency, said conductors being angularly disposed at an acute angle with respect to each other, each conductor making the same angle with, but lying on opposite sides of a line representing the desired direction of radiant action, and a U-shaped metallic circuit having legs substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together.

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35 44. An antenna arrangement comprising a pair of conductors each of a length including several half wave lengths long at the operating frequency, said conductors being angularly disposed with respect to each other, each conductor making the same angle with, but lying on opposite sides of a line representing the desired direction of radiant action, and a circuit having conductors substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together, and means for effectively connecting together for high frequency currents, similarly located points on each of said parallel conductors.

36 45. An antenna arrangement comprising a pair of conductors each of a length including several half wave lengths long at the operating frequency, said conductors being angularly disposed with respect to each other, each conductor making the same angle with, but lying on opposite sides of, a line representing the desired direction of radiant action, a U-shaped circuit having legs substantially parallel to each other connected between substantially opposite points on said angularly disposed conductors, which points are relatively close together, and a transmission line connected to the legs of said U-shaped circuit and to said angularly disposed conductors for energizing said conductors in phase opposition.

37. A directional antenna comprising a pair of angularly disposed substantially straight conductors, said conductors being angularly disposed with respect to each other, each conductor being of a length including a plurality of half wave lengths long at a desired operating frequency, means for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon whereby radiant action of the system formed by said angularly disposed linear conductors is predominantly along the direction of the bisector of the angle formed by the conductors, another pair of conductors parallel and similar to said first mentioned pair of conductors, and a substantially radiationless transmission line, not less than a quarter wave length long at the desired operating frequency, joining substantially opposite points on said pairs of conductors, the points on each pair being relatively close together.

38. A directional antenna comprising a pair of straight conductors angularly disposed with respect to each other, each conductor being of a length including a plurality of wave lengths long at the operating frequency and being electrically open-ended at their most widely separated ends, means for exciting said conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed thereon, and another pair of open-ended conductors similar and parallel to said first mentioned pair of conductors and being spaced therefrom in a direction along the bisector of the angle of the conductors such that radiant action of said pairs of conductors is substantially unidirectional.

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Claim A. A directional antenna comprising a pair of straight conductors angularly disposed with respect to each other, each conductor being of a length including a plurality of half wave lengths long at the operating frequency, said conductors being electrically open-ended at their most widely separated ends, another pair of open-ended conductors similar and parallel to said first mentioned pair of conductors and spaced therefrom in a direction along the bisector of the angle of the conductors, and a substantially resistanceless transmission line connected between points on said pairs of conductors, the points chosen on each pair being relatively close together, said transmission line being not less than a quarter wave length long at the desired operating frequency.

Claim B. A directional antenna comprising two pairs of conductors, the conductors of each pair being substantially straight and being arranged so as to form substantially a V, each conductor of each of said pairs of conductors being of a length including a plurality of wave lengths long at the desired operating frequency, the most remote ends of the conductors of each pair being electrically open-ended, both pairs of conductors lying in the same plane and symmetrically about a line representing a desired direction of radiant action.

#1 50. A directional antenna comprising two pairs of conductors, the conductors of each pair being substantially straight and being arranged so as to form substantially a V, each conductor of each of said pairs of conductors being a plurality of wave lengths long at the desired operating frequency, the most remote ends of the conductors of each pair being electrically open-ended, both pairs of conductors lying in the same plane and symmetrically about a line representing a desired direction of radiant action, and a substantially resistionless transmission line not less than a quarter wave length long connected between similar points on said pairs of conductors, the points taken on each pair of conductors being close relative to the electrical open ends of said conductors.

REMARKS

Applicant is grateful to the Examiner for his very kind suggestions and has attempted to comply with all the Examiner's suggestions so that this application may pass for issue at a date as early as possible.

The specification has been extensively revised in the interest of clarity, to overcome obvious typographical errors, and to correct unidiomatic expressions.

Claims 13, 14 and 19 have been amended to recite that there are means provided for causing standing waves to exist throughout the length of the antenna conductors, a feature which applicant fails to find in Lindenblad.

Claims 13 and 14 have been further amended to overcome the objection raised by the Examiner, which, it is submitted, is not clearly understood since all apparatus claims are for "particular specific designs" no matter what their form. It is herein repeated that these claims define a precise relation between the angle and the length of the antenna, which is not to be found in the Lindenblad patent. Applicant recognizes that the Lindenblad patent broadly covers the present arrangement. However, applicant's concept of specific relations is clearly lacking in the Lindenblad disclosure, and nothing disclosed by Lindenblad appears to meet the present claims.

A somewhat similar situation appears in Hogan vs. John Wanamaker Company, 4 U. S. Pat. Q. 118, at 122, wherein the Court held in connection with two patents, one of which broadly covered a ratio between conductance and capacity in a system and the other of which recited a specific one to one ratio, that:

> "So far as the Lowenstein patent (1618017) is concerned, ...upon..reflection and hearing the arguments in this case, I am satisfied that Lowenstein in dealing with the equality of ratios between inductance and capacity in the two circuits, and particularly with their logarithmic relationship, may have necessarily included in his general conception the idea of a one-to-one ratio which is in fact what Hogan insists upon throughout.
>
> "But Lowenstein is not prior art to Hogan. To defeat the Hogan patent there must be found in Lowenstein the invention disclosed by Hogan. By that I mean that it is not enough to find in Lowenstein a statement of the theory from which one might at once conceive Hogan's idea and consummate his invention. There must, I think, be a disclosure of what he invented; otherwise Lowenstein is in the position of having conceived a general principle without reducing it to the means which constitute invention and of having overlooked that which Hogan conceived and did reduce to operative means."

Similarly, in the present citation, Lindenblad necessarily has included in his general conception the thought of a V type antenna, but he did not include the definite, precise relation between the angle and the length of the antenna for giving the best results. However, this is now considered to be a moot question since the amendments to these claims are considered to render them patentable regardless of this authority, which clearly supports applicant's contention that the claims are allowable. Reconsideration is requested.

Claims 24, 25, 26, 28, 29, 31, 32, 34, 35, and 36 have been amended along the lines suggested by the Examiner, in order to overcome such objections as indefiniteness and incompleteness, and for this reason are now considered to be allowable.

Claim 30 has been cancelled without prejudice, merely to expedite the prosecution of this case.

Claims 5-12, 15-18, 20-22, 33, 39, and 40 stand allowed.

Eight new claims, 43-50, inclusive, have been added to more adequately protect the invention. Claims 43, 44 and 45 have been drawn to read on applicant's Figure 8C and claims 46, 48 and 50 to read on applicant's Figure 5. Claim 47 is somewhat along the lines of allowed claim 5 and claim 46 is drawn somewhat along the lines of claim 47. These claims have been especially drafted in the light of the art cited and clearly distinguish thereover for reasons which it is deemed obvious from a mere reading thereof. These claims recite various limitations not to be found in the prior art, so far as applicant is aware.

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Applicant earnestly submits that he dislikes very much the piecemeal prosecution of claims, and regrets the necessity which requires that he present these claims at this time, which he believes he is clearly entitled to in order to adequately protect his invention.

In view of the fact that the claims now appearing in this application clearly distinguish over the references, it is earnestly requested that an early action be given, so that this case may pass to issue soon.

Respectfully submitted,

PHILIP S. CARTER

By _____
Attorney

CHB:EB

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United States Patent Office

Application of Philip S Carter
For
Serial No 460,467
Div of
Last Office action

entered
filed June 11, 1930
Paper No 6 & 8
April 11, 1934

PATENT OFFICE
MAY 15 1934
PATENT OFFICE
MAY 15 1934

Hon Comm of Patents: Washington, D.C. May 15, 1934

Please amend the above entitled application as follows:

Claims 24, 27, 28 and 29, cancel the period at the end, and add -- , and means for connecting the apex of each V antenna to high frequency apparatus. ---

In Claim 27, lines 1 and 2, change "two pairs" to -- a pair --

Respectfully submitted
P. S. Carter

by H. D. Brown
Attorney

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MAY 1934

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF	PHILIP S. CARTER
FOR	ANTENNAE
SERIAL NO. 460,447	FILED JUNE 11, 1930
DIVISION 51	ROOM 5628

PATENT OFFICE
MAY 21 1934

New York, New York May 15, 1934

HON. COMMISSIONER OF PATENTS
WASHINGTON, D. C.

SIR:

Please amend the above entitled application as follows:

Claim 27, lines 1 and 2, change "two pairs" to --a pair--;

Claims 24, 27, 28, and 29, last line of each claim, change the period to a comma and add:

--and means for connecting the apex of each V antenna to high frequency apparatus--.

Respectfully submitted,
PHILIP S. CARTER

By H. G. Grover
Attorney

CHD:EB

Application filed June 11, 1930
Amendment filed May 15, 1934
in Patent Office

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v. 51, Room 5628
ADDRESS ONLY
THE COMMISSIONER OF PATENTS
WASHINGTON, D.C.
MCG

Serial No. 460,467

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE

Philip Staats Corter, Assor. WASHINGTON June 13, 1934.

Your APPLICATION for a patent for an IMPROVEMENT in ANTENNAE

filed June 11, 1930 has been examined and ALLOWED with 31 claims.

The final fee, THIRTY DOLLARS, WITH $1 ADDITIONAL FOR EACH CLAIM ALLOWED IN EXCESS OF 20, must be paid not later than SIX MONTHS from the date of this present notice of allowance. If the final fee be not paid within that period, the patent will be withheld, but the application may be renewed within one year after the date of the original notice with a renewal fee of $30 and $1 additional for each claim in excess of 20.

The office delivers patents upon the day of their date, on which date their term begins to run. The preparation of the patent for final signing and sealing will require about four weeks, and such work will not be begun until after payment of the necessary final fee.

When the final fee is paid, there should also be sent, DISTINCTLY AND PLAINLY WRITTEN, the name of the INVENTOR, TITLE OF THE INVENTION, AND SERIAL NUMBER AS ABOVE GIVEN, DATE OF ALLOWANCE (which is the date of this circular), DATE OF FILING, and, if assigned, the NAMES OF THE ASSIGNEES.

If it is desired to have the patent issue to an ASSIGNEE OR ASSIGNEES, an assignment containing a REQUEST to that effect, together with the FEE for recording the same, must be filed in this office on or before the date of payment of the final fee.

After issue of the patent, uncertified copies of the drawings and specifications may be purchased at the price of TEN CENTS EACH. The money should accompany the order. Postage stamps will not be received.

The final fee will NOT be received from other than the applicant, his assignee or attorney, or a party in interest as shown by the records of the Patent Office.

NOTICE.—WHEN THE NUMBER OF CLAIMS ALLOWED IS IN EXCESS OF 20, NO SUM LESS THAN $30 PLUS $1 ADDITIONAL FOR EACH CLAIM IN EXCESS OF TWENTY CAN BE ACCEPTED AS THE FINAL FEE.

Respectfully,

Commissioner of Patents.

H. G. Grover,
c/o Radio Corporation of America,
30 Rockefeller Plaza,
New York, N. Y.

IN REMITTING THE FINAL FEE GIVE THE SERIAL NUMBER AT THE HEAD OF THIS NOTICE.

UNCERTIFIED CHECKS WILL NOT BE ACCEPTED.

PAPER NO 17
AMENDMENT

4705

JUL 1234
U.S. PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF	PHILIP S. CARTER
FOR	ANTENNAE
SERIAL NO. 460,487	FILED JUNE 11, 1930
DIVISION 52	ROOM 5628
ALLOWED	JUNE 13, 1934

New York, New York
July 10, 1934

PATENT OFFICE
JUL 13 PM
DIV 5 FILED

HON. COMMISSIONER OF PATENTS
WASHINGTON, D. C.

SIR:

AMENDMENT UNDER RULE 78

Please amend the above entitled application as follows, under the provisions of Rule 78:

Page 1, of the amendment dated May 2, 1934, line 3 from the bottom, after "energized" insert --in phase opposition--;

Page 2, of the amendment dated May 2, 1934, line 13, after "waves" insert --of opposite and instantaneous polarity--;

line 17, rewrite this line as follows:

--rangement is bidirectional.--.

Page 3, of the specification, cancel the second and third paragraphs and substitute therefore:

--A still further object is to concentrate the beam in planes transverse to the plane of the wires. These transverse planes usually include the vertical plane, since the wires are ordinarily disposed in horizontal planes. This may be effected by placing similar arrangements of wires above or below a given arrangement of wires. To increase horizontal directivity, the arrangements of wires may be duplicated side by side.--

Page 3, line 5 from the bottom, change "conal" to --conical--.

Page 4, line 7, change "figure 2," to --any of the figures 2a, 2b, or 2c,--;

line 10, change "figure 2," to --figures 2a, 2b, and 2c,--;

line 13, cancel "an antenna";

rewrite line 14 as follows:

--one antenna system of particular dimensions of the type shown in figure 5,--;

line 20, before "in plan" insert --schematically--;

cancel the last paragraph and substitute:

--Figure 12 is a graph showing the relationship between the length of one of a pair of conductors and half the angle between them for obtaining maximum radiation along the bisector of said angle. As indicated by the sketch of the antenna system in the upper right hand corner of this figure, this relationship holds most strictly when the wires are of equal length.--

Page 5, line 5, change "For a given wire having a given wave length" to read:

--For a given length of wire measured in wave lengths--;

line 10, cancel "a wire which is" and substitute

--the radiation from a wire, which wire is--;

line 14, before "lobes" insert --ears of--;

cancel line 16 and substitute:

--by adjacent ears are reversed.--;

line 18, change "figure 2," to --figures 2a, 2b, and 2c,--;

line 25, cancel "radiation cancellation";

cancel lines 26-29, inclusive, and substitute:

--addition of radiation from the two wires is imperfect, and at certain angles radiation cancellation will occurs. Consequently, a pair of wires disposed at the angle α with respect to the X-X axis will have a

radiation characteristic in the plane of the pair of wires of the general type shown in figure 3.

Page 6, last paragraph, line 2, cancel ", of course,";

line 3, cancel "the wire" and substitute:

--each wire of the V--;

line 5, change "the critical" to --this--.

Page 7, cancel line 3 and substitute:

--pair of wires of substantially equal length are used to form the V antenna of the present invention,--;

line 4, after "angle" (first occurrence) insert --substantially--;

line 8, change "figure 2" to --figures 2a, 2b, or 2c--;

line 15, change "are" to --may be--;

line 17, cancel "of course,";

cancel lines 18 and 19, and substitute:

--2b, the radiating wires may be terminated on a transmission line 10 instead of being connected together at the apex as shown in figure 2a.--

line 20, cancel ", however,";

line 21, change "allows of" to --facilitates--;

line 23, after "are" insert --bridged or--;

line 24, before "short" insert --bridging or--;

cancel the addition to the last line, and substitute:

--in order that reflection along transmission line 10 may be reduced.--

Page 8, line 3, after "unit" insert --substantially --;

line 5, after "is" insert --substantially--;

line 10, change "short circuiting" to --bridging--;

lines 14-15, cancel the insertion made therein and substitute:

--It should be noted that energy should be fed

so as to energize the radiators A,B in phase opposition, otherwise at a distant point P along the axis X-X there would be radiation cancellation instead of addition. It is also to be distinctly understood that the unit, so far described, is not only useful for radiation purposes in a transmitting arrangement but may be

lines 24 and 25, cancel "provided they are placed at the correct angle for their particular length." and insert a period after "desired length" in line 24.

line 3 from the bottom, change "where" to --whether or not--;

line 2 from the bottom, change "does not correspond to a whole" to --corresponds to an integral--.

Page 9, cancel line 11 and substitute:

--by a substantial spacing of preferably not less than one-half wave---

line 12, cancel "apart";

line 17, cancel "With respect";

cancel lines 18-22, inclusive;

line 23, change "approaches" to --for wires whose lengths approach--.

Page 10, in the paragraph substituted for the first paragraph by amendment dated May 2, 1934, line 3, change "Figure 2" to --figures 2a, 2b, and 2c--.

Page 10, line 29, cancel "32, 32'." and insert --at 32, 32', similar to 14 at figure 2c and as shown in figure 11.--;

line 30, cancel "Of course, and/" substitute --By--.

Page 11, line 7, insert a comma after "lines";

line 14, cancel "By making the phase differ-";

cancel lines 15-20, inclusive, and substitute:

--By employing a large number of units, as illustrated, and following the principles of spacing and phasing set forth herein, great directivity may be obtained.--.

Page 12, line 15, change "12" to --10--;

line 21, change "should" to --may--;

line 22, cancel "for maximum concentration,";

line 23, change "length" to --lengths--;

line 25, cancel ", of course,";

line 27, start a new paragraph with the sentence starting "The wires,";

Add the following paragraph at the end of the page:

--By the term "plurality of wave lengths", or "plurality of half wave lengths", or "several half wave lengths" appearing in the appended claims, it is not intended that the wires so described shall necessarily be an exact or approximate integral number of such lengths, but rather that each of the wires so described shall be sufficiently long to include the lengths specified, as is evident from a reading of the specification and drawings.--.

Claim 7, line 2, cancel the insertion therein and substitute:

--said conductors being angularly disposed with respect to each other--.

Claim 42, line 6, cancel "a" (second occurrence).

Claim 47, line 5, after "of" insert --half--.

Claim 50, next to the last line, after "close" insert

--together--.

REMARKS

The above amendments to the specification and claims are intended to clarify the specification and certain of the claims by overcoming ambiguous expressions and obvious inadvertent typographical errors.

In view of the very minor changes made, it is not believed necessary to enter into any discussion with regard to the amendments.

A separate letter is being sent to the Office draftsman requesting him to insert two reference characters, omitted from figure 11, and to correct the omission of two bridging legs in figure 5, in the manner indicated in red ink on the accompanying prints. A mere reading of the specification will show that these corrections are intended to overcome inadvertent errors on the part of the draftsman.

A supplemental Oath, properly signed and executed, accompanies this amendment. It is requested that this Oath be entered for purposes of the record.

Early notice of the entrance of this amendment under Rule 78 is respectfully requested.

Respectfully submitted,

PHILIP S. CARTER

CHB:EB

By H. B. Brower
Attorney

ENTRY RECOMMENDED UNDER RULE 78

EXAMINER

87 81

#17

U.S. PAT. OFFICE

JUL 12

PATENT DIVIS

PATENT DIVISION

JUL 12 34

U.S. PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

In re: Philip S. Carter		
Serial No. 460,467		Division 51
Filed June 11, 1930		Room 5628
Antennae		Allowed June 17, 1934

PATENT OFFICE

JUL 13 1934

DIV. 51 FILED

SUPPLEMENTAL OATH

State of New York)
County of Suffolk) ss:

PHILIP S. CARTER, whose application for Letters Patent for an improvement in ANTENNAE, Serial No. 460,467, was filed in the United States Patent Office on or about the 11th day of June, 1930, being duly sworn, deposes and says that the subject matter of the amendment under Rule 78, filed herewith, and all previous amendments, including, specifically, those filed on November 17, 1931, August 6, 1932, February 10, 1934, and May 3, 1934, was part of his invention, was invented before he filed his original application, above identified, for such invention, was not known or used before his invention, was not patented or described in a printed publication in any country more than two years before his application, was not patented in a foreign country on an application filed by himself or his legal representatives or assigns more than twelve months before his application, was not in public use or on sale in this country for more than two years before the date of his application, and has not been abandoned.

Philip S. Carter

Sworn to and subscribed before me this 10. day of July, 1934.

Ludwig A. Batterman
Notary Public
LUDWIG A. BATTERMAN
NOTARY PUBLIC,
Suffolk County,
Certificate Expires March 30th, 1935

Seal.

82

U.S PATENT OFFICE

JUL 12 1934

RECEIVING DIVISION

MAILED

JUL 12 34

U.S. PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF	PHILIP S. CARTER
FOR	ANTENNAE
SERIAL NO. 460,467	FILED JUNE 11, 1930
DIVISION 51	ROOM 5698
ALLOWED	JUNE 13, 1934

JUL 13 1934

New York, New York
July 10, 1934

HON. COMMISSIONER OF PATENTS
WASHINGTON, D. C.

ACCOUNT

SIR:

ATTENTION: OFFICE DRAFTSMAN

Please instruct the Office draftsman to correct Fig. 5 and Fig. 11 as indicated in red ink on the accompanying print.

The cost of this work is to be charged to the account of Radio Corporation of America.

Respectfully submitted,

PHILIP S. CARTER

By _____
Attorney

Approved

RECEIVED IN DIV. 8
JUL 14 1934

CHB:EB

Encl.

RECOMMENDED UNDER RULE 78

EXAMINER

CORRECTION ORDERED
JUL 14 1934

DIV. 8
CORRECTED
JUL 14 1934

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Fig. 3

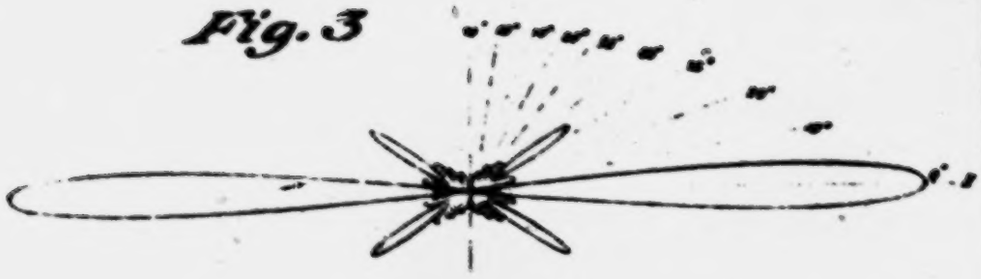


Fig. 4

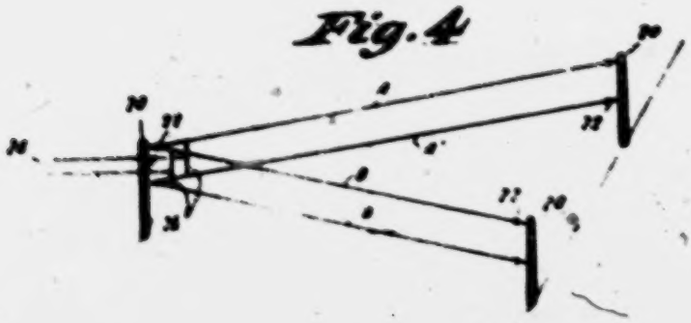


Fig. 5

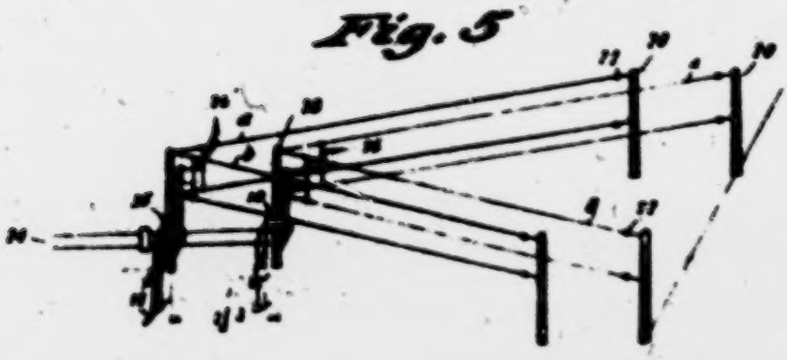


Fig. 6

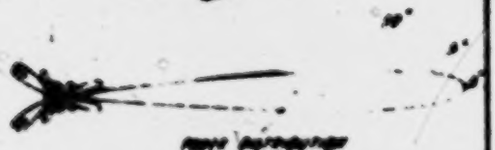


Fig. 7



INVENTOR
P. S. CARTER
BY H. P. Gardner
ATTORNEY

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Fig. 8

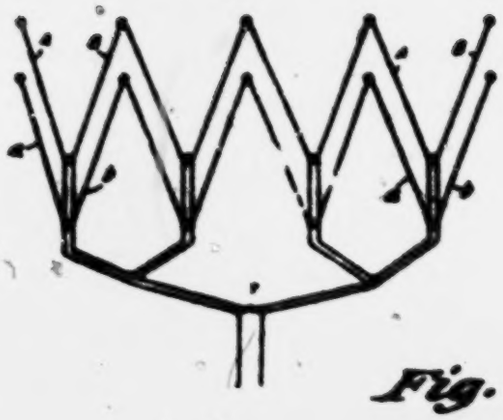


Fig. 10



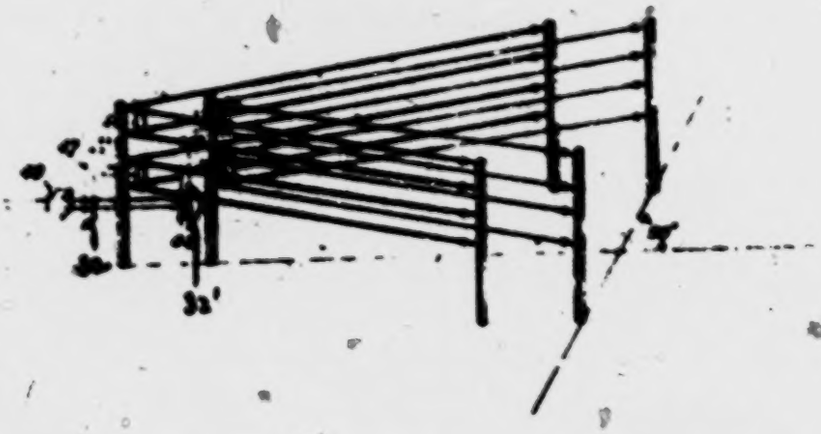
Fig. 10a



Fig. 9



Fig. 11



INVENTOR
P. B. CARTER
BY
ATTORNEY

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DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

July 12, 1937

Petition under **RULE 78:**

Application of

Serial No.

Invention:

FILED

JUL 19 1937

This petition is referred to Examiner in charge of Division 51 in accordance with Order No. 3008; Order No. 3091, 508 O. G., 647, and Notice of August 11, 1932.

Commissioner of Patents.

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DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

July 18, 1934.

Applicant: P. S. Carter

Ser. No. 460,467
Filed June 11, 1930
For Antenna

E. G. Grover,
C/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N. Y.

The entry of the amendment proposed under Rule 78 has been disapproved. A copy of the examiner's adverse report appears below.

JUL 19 1934

Commissioner of Patents

The amendment proposed is more extensive than is contemplated under Rule 78 and contains many proposed changes of questionable propriety. However, most of the changes are approved but the following changes are not approved.

On page 3 of the amendment lines 6, 21, 22 and 28; page 4, lines 8-14, and page 5, lines 1-7 as these changes modify the disclosure to too great an extent.

On page 4, lines 19-22, the proposed changes render this portion incomplete and indefinite.

On page 5, lines 14-28 the additional paragraph is considered unwarranted.

And page 5 the amendment to claim 47 changes the meaning thereof.

The amendment is approved and has been entered except for the above specified exceptions.

The amendment to the drawing has been approved.

Examiner

APPROVED

JUL 17 1934

MAIL ROOM
AUG -3 1934
PATENT

PATENT OFFICE
AUG 3 1934
DIVISION

IN THE UNITED STATES PATENT OFFICE

APPLICATION OF PHILIP S. CARTER		
FOR ANTENNAE		
SERIAL NO. 460,467	FILED JUNE 11, 1930	
DIVISION 51	ROOM 5528	
ALLOWED	JUNE 13, 1934	

PATENT OFFICE
AUG 4 1934

New York, New York. August 2, 1934

HON. COMMISSIONER OF PATENTS
WASHINGTON, D. C.

Rule 78

SIR:

AMENDMENT UNDER RULE 78

Please amend the above entitled application under the provisions of Rule 78, as follows:

Page 8, line 3 from the bottom, change "where" to --whether or not--.

line 2 from the bottom, change "does not correspond to a whole" to --corresponds to an integral--.

Page 9, line 17, cancel "with respect":

cancel lines 18-22, inclusive, including the insertion appearing for these lines:

line 23, change "approaches" to --for wires whose lengths approach--.

Page 12, add the following paragraph at the end of the page

K'

By the term "plurality of wave lengths", or "plurality of half wave lengths", or "several half wave lengths", it is not intended that the wires so described shall necessarily be an exact or approximate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified.

Claims 5, 6, 7, 8, 9 and 10, line 2 of each claim, before "sub stantially" insert --of a length including--;

line 3 of each claim, cancel "long".

Claims 5 and 6, line 2 of each claim, after "and" insert --being--.

Claim 25, line 2, after "each" (second occurrence) insert --of a length including--;

line 3, change "long and" to --and being--;

line 5, after "also" insert --of a length including--;

same line, change "long and" to --and being--.

Claim 31, line 3, before "substan-" insert --of a length including--;

line 4, cancel "long".

Claim 32, line 3, after "each"(second occurrence) insert --of a length including--;

line 4, cancel "long and" and substitute --and being--.

Claims 33 and 34, line 3 of each claim, after "each" (second occurrence) cancel "conductor being" and substitute --conductor being of a length including--;

line 4 of each claim, cancel "long and" and substitute --and being--.

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Claims 39 and 40, line 3 of each claim, before "substantially" insert --of length including--;

line 4 of each claim, change "long and" to --and being--.

Claims 43, 44 and 45, line 2 of each claim, after "each" — insert --of a length including--;

same line of each claim, cancel "long".

Claim 46, line 4, after "being" insert --of a length including--;

same line, cancel "long".

Claim 47, line 3, after "being" insert --of a length including--;

same line, cancel "long".

Claim 48, line 3 after "being" insert --of a length including--;

line 4, cancel "long".

Claims 49 and 50, line 4 of each claim, after "being" insert --of a length including--;

line 3 of each claim, cancel "long".

REMARKS

In accordance with the interview kindly granted applicant's attorney, applicant is presenting herewith several amendments to the application under the provisions of Rule 78. These amendments are similar or identical in scope with those previously presented by applicant in his amendatory paper dated July 8, 1934, and which were not approved by the Examiner. These amendments, it is earnestly submitted, are intended to overcome expressions of poor form and ambiguous terminology.

The addition of the paragraph at the end of page 12 is intended to clear up any possible ambiguity which might exist due to a misinterpretation of the phraseology of the specification and claims. This paragraph, it is to be noted, is now in the form approved by the Examiner, in that it no longer can be interpreted as effecting an amendment to the claims, and therefore of "questionable propriety" under Rule 78. As suggested at the interview, claims 5-10, inclusive, 26, 31, 32, 33, 34, 39, 40, and 43-50, inclusive, have now been amended to conform to the phraseology of the previously requested insertion at the end of page 12.

At this time applicant's attorney desires to express his appreciation of the Examiner's explanation that the characterization of certain previously proposed amendments as "of questionable propriety", in the first paragraph of the Office Letter of July 18, 1934, was intended as a statement that applicant could not, as a matter of right, require the entrance of these amendments under Rule 78, and that the Examiner agrees that the proposed changes were properly within the scope of the invention, as described in the application. We are grateful for the further assistance that the Examiner has given in the present effort to remove all ambiguities from this highly technical application.

Respectfully submitted,

PHILIP S. CARTER

By _____
Attorney

CSB:SB

ENTRY RECOMMENDED
UNDER RULE 78.

_____
EXAMINER

_____

_____

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Aug. 4, 1934

Petition under RULE 78:

Application of

Serial No.

Invention:

MAILED
AUG 8 1934

This petition is returned to Examiner in charge of Division 51 in accordance with Order No. 2008; Order No. 2021, 399 O. G., 447, and Notice of August 11, 1922.

Commissioner of Patents

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Div. 51 Room 5428

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON August 8, 1934.

Paper No. 20

MDG

E. O. Grover,
C/o Radio Corp. of America,
20 Rockefeller Plaza,
New York, N. Y.

Applicant: Philip S. Carter

Ser. No. 680,467
Filed June 11, 1933
For Antennae

The amendment proposed has been entered under Rule 78.

Commissioner of Patents

MAILED
AUG 8 1934

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U. S. PATENT OFFICE
AUG 22 1934
RECEIVED

UNITED STATES PATENT OFFICE

PATENT OFFICE
AUG 22 1934
RECEIVED

APPLICATION OF: PHILIP S. CARTER
FOR: ANTENNAE
SERIAL NO. 460,467 FILED: June 11,1930
DIVISION: 51 ROOM: 5628
LAST OFFICE ACTION: AUGUST 8, 1934

New York, N. Y., August 21, 1934.

COMMISSIONER OF PATENTS
WASHINGTON, D. C.

DEAR SIR:

AMENDMENT UNDER RULE 78

In accordance with the provisions of Rule 78, kindly amend this case as follows:

Claim 23, last line, before the period insert , the conductors of each pair being excited in phase opposition whereby radiant motion occurs principally in the plane of said conductors and along the direction of said bisector

Claim 24, rewrite the last line as follows: a pair of V-shaped antennae arranged to form a parallelogram, and means for connecting the apex of each V antenna to high frequency apparatus whereby the legs of each V which lie alongside each other are excited in phase opposition so that radiant motion occurs principally in the plane of the V-shaped antennae and principally in a direction along a line joining the apices of said V-shaped antennae

Claim 26, last line, before the period insert --whereby radiant action occurs principally in the plane of said radiators and principally along a line joining the apices of said V-shaped antennae--.

Claim 27, rewrite the last line as follows: directions with respect to the other pair, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the V-shaped antennae and principally in a direction corresponding to the line joining the apices of said V-shaped antennae.

Claim 28, rewrite the last line as follows: in different directions, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the V-shaped antennae and principally in a direction corresponding to a line joining the apices of said V-shaped antennae.

Claim 29, rewrite last line as follows: ther, and means for connecting the apex of each V antenna to high frequency apparatus whereby radiant action occurs principally in the plane of the radiators and principally in a direction corresponding to a line joining the apices of said V-shaped antennae.

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REMARKS.

In order to direct claims 23, 24, 26, 27, 28 and 29 more closely about the subject matter which they are intended to cover, the foregoing changes have been made. Inasmuch as the amendments to the claims are not of such nature as to require further search, it is believed that no objection will be made to their entry and, consequently, early notice thereof is respectfully requested.

Respectfully submitted,

PHILIP S. CARTER,

By _____
Attorney.

HT:EC

ENTRY RECOMMENDED
UNDER RULE 78

EXAMINER

DEPARTMENT OF COMMERCE
UNITED STATES PATENT OFFICE
WASHINGTON

Aug. 22, 1934

PUBLISHED
AUG 25 1934

Petition under RULE 78:

Application of

Serial No.

Invention:

This petition is referred to Examiner in charge of Division 51 in accordance with Order No. 3002; Order No. 3021, 398 O. G., 447, and Notice of August 11, 1933.

460437

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No. 51 Room 5426 DEPARTMENT OF COMMERCE Paper No. 28
UNITED STATES PATENT OFFICE
WASHINGTON August 25, 1934.

H. S. Grover,
C/o Radio Corp. of America,
30 Rockefeller Plaza,
New York, N. Y.

Applicant: Philip S. Carter

Ser. No. 460,437
Filed June 11, 1930
For Antennae

The amendment proposed has been entered under Rule 78.

Commissioner of Patents

PUBLISHED
AUG 28 1934

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AC 2334 3[illegible] R -Dist — 30.00

[illegible] 3[illegible] R -Dist — 21.00

FINAL FEE PAID TO THE COMMISSIONER OF PATENTS

(Be careful to give correct Serial No.)

Serial No. 460,402

INVENTOR:
O. L. Carter

PATENT TO BE ISSUED TO
Radio Corporation of America

NAME OF INVENTOR, AS ALLOWED

DATE OF PAYMENT
August 23, 1934

FEE:
Fifty One Dollars

DATE OF FILING
June 11, 1934

DATE OF CIRCULAR OF [illegible]

The Commissioner of Patents will please apply the accompanying fee as indicated above.

[illegible]
Attorney

SEND PATENT TO
Radio Corporation of America
Patent Department
30 Rockefeller Plaza New York N.Y.

Fees will not be refunded except when due to error in the amount paid, UNLESS A PETITION FOR THE REFUND is filed within two years from the date of payment.

P

4. Patent No. 1,927,522 issued to Nils E. Lindenblad assignor to Radio Corporation of America for Antenna for Radio Communication, granted September 19th, 1933, on an application filed December 24th, 1928, of which claims 9, 10, 19, and 23 are in suit. This patent will be hereinafter referred to as the second Lindenblad patent.

5. Patent No. 1,974,387 issued to Philip Staats Carter assignor to Radio Corporation of America for Antenna, granted September 18th, 1934, on an application filed June 11th, 1930, of which claims 1, 2, 3, 4, 10, 12, 15, 16, 28, 34, 35, 36, 38 and 40 are in suit. This patent will be hereinafter referred to as the third Carter patent.

The first two Carter patents are directed to the subject of impedance matching. The two Lindenblad patents and the third Carter patent are directed to the subject of antennas. I will consider them in the two respective groups.

The defendant by answer has pleaded the defenses of invalidity and non-infringement.

[fol. 1347] The title to the patents in suit is in the plaintiff and notice of infringement was properly given.

There is no dispute as to the construction or arrangement of the defendant's antenna systems and they are fully described in the agreed descriptions, diagrams and tabulations of dimensional data comprising Plaintiff's Exhibits 7 to 13, inclusive. The antennas which are asserted to infringe are known as V-antennas Nos. 1 to 11, inclusive (two of which have been rebuilt) and certain other antennas known as "dipole arrays". The antennas referred to as having been rebuilt are obviously defendant's antennas Nos. 2 and 3, the rebuilding of which was occasioned by commercial requirements of establishing additional communication channels in a different direction from that in which they had previously been used. Various alterations occurred in the rebuilding process and as these rebuilt antennas were not rebuilt until after the main and supplemental bills of complaint were filed in this suit, they cannot properly be considered by this Court under the charge of infringement on the pleadings in this suit.

The desirability for, and the utilization of an impedance matching arrangement was known many years prior to the earliest date which could be claimed by Carter. In the transmission of electrical energy over a line, whenever, as

is usually the case, the impedance of the load differs from the impedance of the transmission line, energy will not flow smoothly into the load, but part of it will be reflected back into the line towards the source of power, and cause "reflection", "standing waves", "reflection loss", etc. Also, when there is a sharp bend in a transmission line a differ- [fol. 1348] ence of impedance results which causes reflection. If, however, the impedance of the load is matched to the impedance of the line there are no reflected waves, and there is obtained what is termed a "reflectionless line", "a traveling wave", a "line of electrically infinite length", etc. These terms (as well as others mentioned on the trial and in the briefs herein) are synonymous and the desirability for impedance matching, as well as the means employed for effecting it, is not concerned with the purpose for which the current being transmitted is used. I can see no difference whether impedance matching be effected in a radio receiving system, a radio transmission system, a telephone line, a power line or in any circuit. The second Carter patent in suit is entitled "Electrical Circuit" and is applicable to any circuit arrangement where efficient transfer of energy, without reflection is desired. Unequal impedance is always the cause of reflected waves and the cure is always equal or matched impedance.

Impedance matching devices for the purpose of preventing reflection on transmission lines have been used for many years in radio transmitting systems, at least, since 1920, and as the first Carter patent in suit was not applied for until 1923 there was nothing novel at that date in the necessity for matching impedances, or in the principle that by matched impedances reflected waves on the transmission line were avoided.

The First Carter Patent No. 1,623,996

This patent is directed to the subject of a reflectionless transmission line obtained by matching the surge impedance [fol. 1349] of the line with the load impedance of the antenna which it feeds. A transformer is the only means shown or suggested for accomplishing that purpose, and two forms of transformers are illustrated, namely the usual two coil transformer illustrated in Figs. 1, 3 and 5, and the auto (one coil) transformer of Fig. 2.

It is pointed out in the patent that in the past it has been the custom to erect the antenna of a transmitting system as close as possible to the point when the radio frequency power is generated in order to have "a minimum power loss between the generator and the antenna". The patentee in his specification states the objects of his invention to be as follows:

"the provision of a transmission line which will supply radio frequency energy from a power-house to an antenna located at a considerable distance away, thus making possible the utilization of existing apparatus at a high efficiency where hitherto only a low efficiency was possible. Another object of the invention is to provide a new and improved system giving directional transmission utilizing separate antennæ fed from a single source through a plurality of transmission lines."

Claims 1, 2 and 5 have to do only with the first stated object. Claim 7 has to do only with the second stated object.

It is pointed out in the specification that in order to attain the first object of the invention it is necessary that the apparatus work

"at unity power factor; that is to say that the current and [fol. 1350] voltage in the transmission line should be in phase."

and the patent further says:

"Such a result may be obtained if the transmission line is made reflectionless or of electrically infinite length. Under these conditions no waves can be reflected back from the ends to interfere with the natural flow of energy into and out of the transmission line."

The invention of the patent consists in making reflectionless the transmission line extending between the source of the current and the load. The patentee says in his specification

"This result may be obtained by closing the transmission line 10 at 11 in such a manner that the effective impedance at the load end of the line is equal to the surge impedance of the transmission line."

This statement means that the impedance of the load is matched to the impedance of the line throughout the entire length thereof.

The problem as stated is how to bring about or produce that condition.

The recital by Carter of what purports to be his solution of the problem amounts simply to this, the antenna resistance multiplied by the square of the feed ratio should be equal to the surge impedance of the line.

This is a statement in terms of results, without any instruction as to how to accomplish these results. The only thing shown in the drawings of the patent for accomplishing the result is a transformer, but there is no statement [fol. 1351] nor is it implied or indicated how the transformer is to be made, adjusted or set up in order to make it possible to close,

"the transmission line 10 at 11 in such a manner that the effective impedance at the load end of the line is equal to the surge impedance of the transmission line."

The first Carter patent in suit is a paper patent and in view of the prior art in evidence to wit: Alexanderson patent No. 1,360,167; Rice and Kellogg patent No. 1,602,085; Colpitts patent No. 1,129,959; Leblanc patent No. 874,411; Heising patent No. 1,313,483; Conrad patent No. 1,640,534; Reuthe patent No. 1,314,095 and Whiting patent No. 1,537,-101, it can be given only a limited range of equivalents sufficient to protect the invention of that patent.

Defendant does not employ any connection between a transmission line and a radiator, where at the point of connection, an impedance matching device is employed.

The defendant in every antenna under charge of infringement in this suit employs an impedance matching device located in the transmission line at a distance from the antenna wires.

No transformer connecting the end of the transmission line with the antenna is used by the defendant in any of its antenna systems under charge of infringement in this suit.

The defendant does not employ a transformer as an impedance matching device in any of its said antenna systems.

Claim 1 recites as the elements of its combination an [fol. 1352] energy radiating circuit (an antenna), a source of power for energizing said circuit (the generator), and a

transmission line of electrically infinite length connecting said circuit and said source.

Fig. 1 of the patent shows the transmission line 10 extending to the antenna, as is necessary in a system where a transformer connects the antenna with the transmission line, and the patent in suit instructs to terminate the line with a transformer.

No such arrangement or any arrangement which might be correctly described by this language is shown in any of the defendant's alleged infringing devices.

This is also true with respect to claims 2 and 5 in suit, the last element in each of which is defined as a reflectionless transmission line connecting the source and the antenna or radiating circuit.

Antenna No. 2, which is typical of its class, shows that the transmission line extends from the transmitter to the radiators (antenna wires ACBD) but the impedance matching device (KLMN) is located on the transmission line a substantial distance from the radiators, therefore defendant does not employ "a transmission line of electrically infinite length connecting the radiator (ACBD) and the source" (the transmitter).

Antenna No. 7 of defendant's devices has reflected waves on the entire portion of the transmission line leading from the power-house to where the transmission line branches, as well as from the radiators to the points E F and E′ F′.

By their terms each of claims 1, 2 and 5 are limited to a [fol. 1353] transmission line connecting the antenna and the source of power which is reflectionless throughout its length.

Defendant does not employ in any of its antenna systems a transmission line connecting the source of current to the radiating antenna, which is reflectionless throughout its length.

In defendant's devices the production of reflected waves on a portion of the defendant's line is a necessary expedient for successful operation and defendant's antenna system could not operate if defendant's arrangement were used in a manner to entirely eliminate reflected waves throughout the length of a transmission line. Defendant's antenna No. 2 (original) best illustrates this point.

Claim 7 of the patent in suit recites as the element of its combination

a plurality of antennae,
a single source for supplying energy to all of said antennae and,
transmission lines of electrically infinite length for supplying energy from said source to said antennae.

It thus appears that claim 7 is limited in addition to the limitations of claims 1, 2 and 5, to at least two transmission lines of electrically infinite length, which supply power from a single source to two or more antennas.

Plaintiff attempted, but unsuccessfully, to apply this claim to defendant's antenna systems like antenna No. 8.

From a careful consideration of the evidence, it appears that the defendant's devices, which are alleged to infringe, use a radically different arrangement to accomplish an old [fol. 1354] result, and irrespective of the validity of the patent in suit or whether or not the claims are readable on defendant's antennas. Westinghouse v. Boyden Power Brake Co., 170 U. S. 537.

The defendant does not infringe the First Carter Patent No. 1,623,996.

The Second Carter Patent No. 1,909,610

This patent like the first Carter patent, is directed to the subject matter of matching the surge impedance of the line to the impedance of the load to which the line feeds. As its object is identical with that of the first Carter patent, which was applied for nearly seven years and issued nearly three years prior to the application of the Second Carter patent, the subject matter of the said Second Carter patent is and must be confined to the particular instrumentalities, arranged in the particular way shown and described by the patent to effect impedance matching.

The Second Carter patent is not specifically directed or limited to use in connection with radio antennas, but to electric circuits in general and for use in any field where reflectionless transmission lines, matched impedances, elimination of standing waves, etc., are desired.

The patentee in his specification says:

"This invention relates to electric circuits and especially to a transmission line supplying high frequency currents to a high frequency load circuit"

and then recites what is well known in the prior art

[fol. 1355] "In order that the line transmit energy at best efficiency; that is to say, without reflection, it is desirable that the line be terminated by a load which equals in impedance the surge impedance of the line."

After noting that lines and loads are independently designed, and that existing lines must be connected with existing loads which do not have the requisite values of impedance for best energy transmission, the patentee states

"it is an object of my invention to provide a method and means for terminating a line to which a load is connected so that the termination means combined with the load presents the correct impedance to the line. More specifically, I accomplish this by connecting a variable reactance across the line at a distance away from the load such that the circuit formed thereby including the variable reactance, the line portion between it and the load, and the load, presents an impedance equivalent to the surge impedance of the line."

On its face the patent admits, in substance at least, that it differs from the disclosure of the first Carter patent only in the specific "method and means for terminating a line."

The patentee then says:

"In a case wherein the surge impedance is greater than the load impedance or resistance, I have discovered that by connecting a capacitive reactance across the line at a dis-
[fol. 1356] tance not more than one-quarter of a wave length of the energy transmitted by the line away from the load; or, by connecting an inductive reactance across the line at a distance more than one-quarter wave length but less than one-half wave length of the load, the combination of the reactance and the load and portion of the line included between the reactance and the load becomes equivalent, with proper quantitative values of the electrical elements involved to the surge impedance of the line, thereby facilitating efficient energy transmission."

and then says:

"Similarly I have discovered that when the surge impedance of the line is less than the load impedance, by connecting an inductive reactance across the line not more than one-quarter wave length away from it; or, a capacitive re-

actance across the line more than one-quarter wave length but less than one-half wave length away from the load, that the combination of reactance, load and portion of the line included between the reactance and the load becomes equivalent, with proper quantitative values of the electrical elements involved to the surge impedance of the line thereby properly terminating it for maximum energy transmission."

From the foregoing quotations from the patent it appears that whether the surge impedance is less or greater than the load impedance, the patentee connects a variable reactance across the line, viz.: in shunt to the load. That where the surge impedance is greater than the load the reactance is [fol. 1357] either capacitive with its point of connection across the line "not more than one-quarter wave length away from the load", or it is inductive located "more than a quarter wave length but less than one-half wave length away from the load". That where the surge impedance is less than the load impedance the resistance connected across the line is either inductive and positioned "not more than one-quarter wave length away from the load", or is capacitive and is connected across the line "more than one-quarter wave length away from the load." That the desired result is attained under either set of conditions only "with proper quantitative values of electrical elements."

The specification describes the arrangements shown in the drawings and sets forth in a table the discovery of the patentee recited in the two paragraphs of the patent hereinbefore quoted.

The disclosure of the patent in brief is that impedance matching may be effected by connecting a variable reactance of proper value across the line at a proper distance from the load. The patent recognizes and twice states that the object of the invention can be attained only "if proper quantitative values of the electrical elements involved" are used, but is silent as to how those values can be ascertained. Further the patent conveys the idea that at any point within a quarter wave length distance from the load (in the one case), or more than one-quarter wave length but not greater than one-half wave length (in the other case), a reactance connected across the line would obtain the desired result,

[fols. 1344-1345] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

Equity. No. 7234

RADIO CORPORATION OF AMERICA, Plaintiff,

against

MACKAY RADIO AND TELEGRAPH COMPANY, INC., Defendant

October 14th, 1936.

Sheffield & Betts, Esqs., Solicitors for Plaintiff; Jo. Baily Brown, Esq., Harry Tunick, Esq., and Abel E. Blackmar, Jr., Esq., of Counsel.

Darby & Darby, Esqs., Solicitors for Defendant; Hugh M. Morris, Esq., Samuel E. Darby, Jr., Paul Kolisch, Esq., and Roy C. Hapgood, Esq., of Counsel.

OPINION

CAMPBELL, D. J.:

This is a suit for the alleged infringement of certain claims of five patents as follows:

1. Patent No. 1,623,996 issued to Philip S. Carter assignor to Radio Corporation of America for Radio Transmission System, granted April 12th, 1927, on an application filed June 25th, 1923, of which claims 1, 2, 5 and 7 are in suit. This patent will be hereinafter referred to as the first Carter patent.

2. Patent No. 1,909,610 issued to Philip Staats Carter assignor to Radio Corporation of America for Electric Cir-[fol. 1346] cuit, granted May 16th, 1933, on an application filed March 12th, 1930, of which claims 1 to 5 inclusive are in suit. This patent will be hereinafter referred to as the second Carter patent.

3. Patent No. 1,884,006 issued to Nils E. Lindenblad assignor to Radio Corporation of America for Antenna, granted October 25th, 1932, on an application filed September 7th, 1928, of which claims 23 to 27 inclusive are in suit. This patent will be hereinafter referred to as the first Lindenblad patent.

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whereas in fact to attain the results of the patent the point of proper connection of the reactance across the line, that [fol. 1358] is its distance from the load, was precise and exact in each instance.

This constitutes the whole disclosure of the Second Carter patent in suit.

All five claims of the patent are in suit and each is for a combination.

Claim 1. The elements of the combination of claim 1 are (1) a source of energy, (2) a load, (3) a transmission line extending between the source of energy and the load and (4) means for matching the load to the surge impedance of the line consisting of

(a) a reactance connected across said line between said load and said source and so arranged that

(b) a portion of said line is located between said reactance and said load,

(c) said reactance having such value that the combination only of the load, portion of the line, and the reactance

(d) becomes equivalent to the surge impedance of said transmission line.

Claim 2 differs from claim 1 in defining the reactance as "a variable element", and in defining the transmission line as "an unbroken linear connection characterized by the absence of serially connected impedances between said source and said load".

Claim 3 is specific to the situation where the transmission line has a surge impedance greater than the load resistance; the shunt reactance being defined as "a capacitive reactance" connected across the line between the load and [fol. 1359] the source a distance from the load not exceeding a quarter wave length.

Claim 4 is likewise specific to the case where the transmission line has a surge impedance greater than the load resistance, but wherein the shunt resistance is inductive and is connected across the line between the load and the source at a distance greater than one-quarter wave length and less than one-half wave length from the load.

Claim 5 is specific to the case where the transmission line has a surge impedance less than the load resistance, and

there is e ployed for the shunt resistance an inductance connected across the line at a distance from the load less than a quarter wave length therefrom.

Claims 3 and 4 are specific in reciting that the transmission line has a surge impedance greater than the load resistance; and Claim 5 in stating that the transmission line has a surge impedance less than the load resistance.

Although plaintiff contends that defendant's antennas infringe all of the claims in suit it has not shown which of the two aforesaid conditions prevails in any of defendant's antennas.

In view of the first Carter patent in suit, Whiting patent 1,537,101, British patent to Franklin 282,905 and Lindenblad patent 1,884,006, the Second Carter patent in suit cannot have a wide range of equivalents but must be limited to the protection of the invention of the Second Carter patent in suit, which is confined to the particular instrumentalities, arranged in the particular way shown and described by the [fol. 1360] patent to effect impedance matching.

The main object of the Second Carter patent in suit is to provide a transmission line reflectionless throughout its length and none of defendant's transmission lines is reflectionless throughout its length.

This has been fully discussed in this opinion in my consideration of the charge of infringement of the First Carter patent in suit and need not be repeated.

To accomplish its object the Second Carter patent in suit discloses only the connection across the transmission line of a lumped capacitance or a lumped inductance, as specified in each of the claims of the patent in suit and which as additionally provided in Claim 2, must be variable.

There is no lumped reactance connected across the line in any of defendant's structures. What defendant uses in every instance, is a plain wire which has only distributed inductance and distributed capacitance. In no instance is the wire a variable element, as shown, described and claimed in the patent in suit. The only way the patent could be practiced at the time of its application was to experimentally ascertain the value of the reactance by the method of actually varying the value thereof, and therefore variability becomes a necessary limitation in each of the claims whether expressed therein or not.

The loops of the wire of the defendant's device are not variable in the sense in which a lumped condenser or induction coil is variable. It is true that by cutting off pieces of wire defendant's devices can be varied in one direction but [fol. 1361] the word variable as used in the patent does not mean "something which can be changed". Given that meaning, it would lose all sense as there is no element in a radio antenna system that is not variable in that sense. The term variable as used in the patent and shown in the drawings means the ability to increase and decrease the value of the inductance or capacity as the case may be. The defendant employs no variable element in the sense such term is employed either expressly or by inference in all of the claims of the patent in suit.

The plaintiff, on which rested the burden of proving infringement, has failed to bear that burden by offering any proof that in defendant's antenna systems there is a transmission line having a surge impedance greater than the load resistance as specified in claims 3 and 4 or a transmission line having a surge impedance less than the load resistance, as specified in claim 5.

The defendant used instrumentalities which are different in every respect from the instrumentalities which are disclosed in the patent in suit and if the distributed inductances and capacitances as used by defendant in its antennas charged to infringe are the equivalent of the lumped inductances and capacitances of the Second Carter patent in suit (which in my opinion they are not) then the patent would be anticipated by the British patent to Franklin No. 282,905.

Regardless of its validity, the Second Carter patent in suit is not infringed by any of the defendant's alleged infringing devices.

[fol. 1362] Having concluded consideration of the two patents in suit directed to the subject of impedance matching, I will now consider the three patents in suit directed to the subject of the antenna.

As expressly provided in the three antenna patents in suit, the main or principal lobes of radiation or, as it is sometimes termed, the "predominant radiation", must take place in the plane of the antenna wires, and as additionally provided in the second Lindenblad patent in suit and the third Carter patent in suit along the bisector of the V.

The main object of the three antenna patents in suit was to arrange two or more antenna wires so that radiation takes place in the plane of the wires horizontally if the wires are horizontal with respect to the ground and at an angle if the wires are tilted at an angle.

The wires are arranged parallel to one another in the first Lindenblad patent in suit and according to it the principal radiation is concentrated in the plane of the wires as distinguished from prior arrangements in which, according to Lindenblad, radiation took place in other directions outside of the plane.

The purpose of the second Lindenblad patent in suit was to improve on the first Lindenblad patent in suit by concentrating radiation not only in the plane of the wires, but along the axis of the V into which the two wires are formed, which constitutes the bisector of the angle formed by the wires.

The third Carter patent in suit has as its object to improve on the second Lindenblad patent in suit by achieving [fol. 1363] an even greater concentration in the plane of the wires along the bisector of the angle by selection of the proper angle between the legs of the V.

The defendant's antennas which are charged with infringement differ radically from the inventions claimed in the three antenna patents in suit. None of them propagate a main lobe of radiation in the plane of the wires, but intentionally propagate their main lobes of radiation at an angle to the plane of the wires for the deliberate purpose of utilizing the reflective effect of the Heaviside layer.

None of the defendant's antennas tilts the wires at an angle to the horizontal to accomplish this, but that alone, is contemplated by the patents in suit for that purpose. For the same reason, none of defendant's antennas propagates its main lobe of radiation on the axis of the system, or along the bisector of the angle between the legs of the V.

None of defendant's antennas (with the exception of antennas No. 8) uses radiator wires an integral number of half wave lengths long, as is specified by all three of the antenna patents in suit, but the defendant's radiator wires depart from the half wave length measure as far as it is possible so to do. This is done for the deliberate purpose of creating standing waves on a portion of the transmission line feeding

the antenna as is necessary in order to tune the antenna and effect impedance matching in defendant's system.

None of defendant's antennas utilize an angle between the legs of the V that is dependent upon the Carter formula as well as the Abraham formula, and this is especially true of defendant's aforesaid antenna No. 8, but also true as to the remainder of the antennas as Carter's formula is predi- [fol. 1364] cated upon the precise relation between the angle of propagation and the exact length of the antenna wires, which must be an integral number of half wave lengths in order to be accurate.

In substance all of the antenna patents in suit present merely a theoretical application of antenna wires in free space, whereas all of the defendant's are intentionally designed to co-operate with ground effect, which effect not only is not contemplated by any of the patents in suit, but is contradictory to the description and claims thereof.

The First Lindenblad Patent No. 1,884,006

This patent is directed to the use of staggered parallel wires as an antenna.

No evidence was offered which showed the adoption of this type of antenna by anyone, and defendant does not use parallel or staggered wires. To attain the stated objects of the patent by the use of parallel wire antennas, there must be proper spacing between the wires. This fact is expressly recognized by the patent which expressly misdirects with respect thereto. And the patent is expressly directed to obtain propagation of waves in the plane of the wires.

Figs. 1 and 2 of the drawings of the patent illustrate the well known single wire antenna which is characterized by the patent as "wasteful of energy".

The patentee in the specification says one object of his invention is

"to reduce the conical radiation so that it will consist only of concentrated lobes having axes in one plane. This is [fol. 1365] accomplished by providing two collaterally spaced substantially parallel linear conductors which are long, relative to the working wave length, and which are coupled in phase opposition."

This arrangement is shown in Fig. 3 and on comparison with Fig. 2 it will be seen that the conical radiation has been reduced by means of the parallel wire arrangement, to four

principal lobes of radiation 30, 34, 32 and 36, all in the same plane of the wires.

The patent also states:

"This arrangement, too, is wasteful of energy, and it is a further object of my invention to strengthen the radiation in one pair of opposite critical directions, while weakening the radiation in the conjugate pair of opposite critical directions, which I do by staggering the pair of wires, longitudinally, so that their ends make an angle with the transverse axis of the antenna equal to the critical angle of radiation, that is, the angle which the principal lobes of the radiation pattern of the antenna make with the longitudinal axis of the antenna."

Fig. 4 of the drawings shows this arrangement and on comparison with Fig. 3 it shows that two additional lobes in the same general direction have been joined, still in the plane of the wires. Only by staggering the ends of the parallel wires and spacing them from each other a proper distance can this effect be produced. A bidirectional antenna is secured in this way. To make the system unidirectional, [fol. 1366] as illustrated in Fig. 5 for example, a "reflector" is used, that is a duplication of the staggered parallel wires but, spaced therefrom a proper distance in the manner taught in the First Carter Patent, for example, which was admittedly old even at the date of Carter's first application 1923.

Every objective attained or sought to be attained thereby, is dependent upon the proper spacing between parallel wires.

In Fig. 4 is illustrated the subject matter of spacing between the parallel wires where it is shown that the wires are spaced from each other a distance determined by the formula recited, which distance is measured in the direction of radiation. This was an entirely erroneous teaching, and was not merely a draftsman's error or oversight as the mistake was carried into the text also where the erroneous is thrice supported in the specification.

Claims 23, 24, 25, 26 and 27 are in suit and claim 23, which may be taken as typical, reads as follows:

"23. A directional antenna comprising a pair of long linear wires connected at adjacent ends to high frequency apparatus and having standing waves of opposite instantaneous polarity thereon, said wires being several wave

lengths in length and extending away from and on one side only of said adjacent ends."

All of the claims in suit must necessarily be read in the light of the disclosure of the patent; that is they must be [fol. 1367] read as being directed to cover staggered, parallel wires employed as radiators from which radiation is effected in the plane of the wires. Unless the claims be so interpreted, they would fail to describe the invention of the patent as specified therein.

All of the claims in suit contain the limitation that the wires are "several wave lengths in length", and claims 25, 26 and 27 expressly recite that the wires are arranged so that radiant action occurs in a direction making the same angle with each conductor, which means that the wires are parallel to each other.

A consideration of the evidence leads me to the conclusion that regardless of the validity of the patent none of the defendant's antennas infringes the first Lindenblad patent in suit for the following reasons:

None of the defendant's antennas radiates waves in the plane of the wires, but in all of them the main lobe of radiation is at an angle to the plane of the wires.

None of the defendant's radiating wires or conductors is arranged parallel to each other but all of defendant's wires are in the form of a V.

None of defendant's antennas is longitudinally staggered with respect to one another in order to obtain bidirectional effect, but the open ends of the legs of defendant's V terminate opposite each other.

None of defendant's bidirectional antennas employ a pair of wires spaced from each other in accordance with the spacing formula, whether correctly applied or incorrectly applied as in the first Lindenblad patent in suit, but defend- [fol. 1368] ant's single V antennas are bidirectional without using this feature.

None of defendant's antennas employ, in order to obtain unidirectivity, a reflector of parallel spaced staggered wires, but employs as its reflector another V antenna.

Defendant's antennas differ so radically in structure and principle of operation from those of the first Lindenblad patent in suit that if the claims in suit of that patent be even literally readable on defendant's antenna systems and so interpreted as to include within their scope defendant's an-

tennas or any of them, the claims would not define Lindenblad's invention. The claims do not literally read on defendant's antennas as there is of necessity imported into the claims, properly spaced parallel staggered wires, without which the directive system claimed in each of the claims in suit could not be obtained.

The first Lindenblad patent in suit is not infringed.

The Second Lindenblad Patent 1,927,522

This patent is for a traveling wave antenna. No evidence was offered of any adoption or use thereof by anyone. All of defendant's antennas charged to infringe are of the standing wave type. This patent likewise specifically directs and limits its disclosure to the propagation of the main lobe of radiation in the plane of the wires. Defendant does not employ any antenna in which the main lobe of radiation is in the plar. of the wires. This patent is not directed broadly to a V-type antenna as it is wholly inadequate of disclosure because the proper angle betwe-n the antenna [fol. 1369] wires constituting the legs of the V is not given and no means are disclosed by the patent to enable one to determine the proper angle. Only with proper angles could the stated objects of the patent be attained, that is, that the main lobe of radiation would be in the plane of the wires and on the bisector of the angle between the legs of the V.

The patentee in his specification says:

"It is an object of my invention to provide an exceedingly simple form of short wave antenna, which will operate over a considerable range of frequency, and a further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices."

None of defendant's antennas is designed to "operate over a considerable range of frequency", but all of them employ "intermediate impedance matching devices". The patentee then states that the stated object is accomplished by the utilization of traveling waves. All of defendant's are of the standing wave type.

The second Lindenblad patent specifies that the principal radiation occurs in the plane of the wires and says:

"The desired radiation takes place in the direction of the axis of the pair of conductors."

Again reference is made to "radiation in the direction of the antenna".

[fol. 1370] No instruction is given in the specification as to the proper angle between the legs of the V, and such instruction is necessary because without the proper angle, maximum radiation in the direction of the bisector of the angle would not occur, as at certain values of the angle, zero radiation on the line of the bisector is obtained.

Claims 9, 10, 19 and 23 are in suit.

Claim 9 reads as follows:

"9. In combination, a two conductor transmission line excited in phase opposition, and an antenna extending longitudinally in the direction of desired radiant action comprising an open ended pair of conductors which at one end are spaced at the spacing of the transmission line and are coupled thereto, and which gradually diverge to a much wider spacing at their open ends."

Claim 10 also defines the antenna as

"extending longitudinally in the direction of desired radiant action".

These claims are therefore expressly limited to radiation in the plane of the wires.

Claim 19 expressly recites that radiant action

"occurs predominantly along the direction of the axis of the conductor system".

Therefore this claim is also expressly limited to the principal radiation being in the plane of the wires.

Claim 23 expresses the same thought but in different language where it expressly provides that radiant action

[fol. 1371] "occurs predominantly in a direction making equal angles greater than zero degrees".

with reference to the conductors.

As hereinbefore stated none of defendant's antennas are of the traveling wave type and therefore none of the defendant's antennas embody the alleged invention of the second

Lindenblad patent in suit irrespective of the terminology of the claims.

As hereinbefore pointed out the claims in suit show that they are by their terms expressly limited to radiation in the plane of the wires.

None of the defendant's antennas so operate.

Regardless of the validity of the patent the second Lindenblad patent is not infringed.

The Third Carter Patent No. 1,974,387

This patent is also directed to the V-type antenna, and the asserted contribution of the patent over the second Lindenblad patent consists of supplying the necessary formula for determining the proper angle between the antenna wires constituting the legs of the V in order to obtain maximum radiation in the plane of the wires along the line of the bisector of the angle between the legs of the V.

There is no evidence in this case that the defendant or anyone else has adopted or practically used the antenna of this type where radiation is effected in the plane of the wires on the line bisecting the angle between the legs of the V. Defendant deliberately and intentionally propagates its main lobe of radiation at an angle to the plane of the wires. [fol. 1372] The mathematical formula advanced as the invention of the patent was copied from the prior art formula of Abraham which had been used by engineers for determining the identical angle for which it was employed by Carter. This formula as employed by Abraham and Carter gives merely theoretical results, but was advanced by both of them as affording means for determining the angle between the principal lobe of radiation and the wire from which it radiates in free space, when the wire is an integral number of half wave lengths long. Defendant does not use antenna wires an integral number of half wave lengths long (with the exception of antenna No. 8), and antenna No. 8 together with all of the other antennas of defendant, charged herein to infringe, do not employ the angle prescribed by the formula. Defendant does not propagate its main lobe of radiation in the plane of the wires or on the bisector of the angle of the V. Due to the departure from the Carter patent in the respects enumerated and by reason thereof in all of defendant's antennas, here charged to infringe, defendant obtains material advantages and increased effi-

ciency in that material increase in radiated power is obtained.

That main radiation is desired and obtained by the patentee in the plane of the wires, and on the line bisecting the angle of the V formed thereby appears from the specification which says

"It is proposed to place these wires at an angle with respect to each other so that principal radiation takes place along the bisector of the angle" (p. 1, l. 22).

[fol. 1373] and again that the wires are disposed

"at an angle such that the principal radiation occurs along the direction of the bisector of the angle" (p. 1, l. 79).

There will also be found on page 2, lines 32, 34, 39, 44, 101, and on page 3, lines 40, 74, 84, 116 and 131 references of similar character.

The Abraham formula for determining the angle between the legs of the V is copied in the specification.

The application as originally filed was expressly limited in the specification and claims to antenna wires an integral number of half wave lengths long and the Abraham formula would correctly apply thereto.

During the prosecution of the case, and subsequent to the answer of the defendant filed in this suit, the specification was amended by the insertion of the following:

"By the term 'plurality of wave lengths,' or 'several half wave lengths', it is not intended that the wires so described shall necessarily be an exact or approximate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified" (p. 4, ll. 35-42).

and the claims were amended correspondingly and in that form the patent issued. The object was to include an antenna of any length.

The claims in suit are claims 1, 2, 3, 4, 10, 12, 15, 16, 28, 34, 35, 36, 38 and 40.

[fol. 1374] Claims 1-4 are directed merely to the use of a V antenna with its reflector.

Claims 1-3 are expressly limited to the radiant action being

"predominantly along the direction of the bisector of the angle formed by the conductors."

and claims 1-4 were amended subsequent to defendant's answer in this case with reference to the length of the wires so as to "include" substantially a plurality of half wave lengths instead of being expressly limited to an integral number of half wave lengths as they were theretofore drawn.

Claims 10, 12, 15 and 16 all, at least, include as part of the invention of the Abraham formula in some form.

Claim 28 is directed to the reflector feature and contains the amendment as to the length of the wires of the V made after answer in this suit.

Claims 34, 35 and 36 are directed to the use of impedance matching devices with a V-type antenna. They are expressly limited to radiation on the bisector of the angle, and include the belated amendment as to the length of the wire.

Claim 38 differs from claim 1 only in more generally defining the spacing of the reflector, and contains the belated amendment as to the length of the antenna wires.

Claim 40 is directed to the reflector feature with a V antenna and is expressly limited to radiation along the bisector of the angle between the legs of the V.

[fol. 1375] Defendant does not radiate in the plane of the wires, whereas the Third Carter patent in suit is expressly limited as to some claims, and impliedly as to all thereof, to radiation in the plane of the wires and, in fact, on the line bisecting the angle between the legs of the V.

Defendant does not employ antenna wires an integral number of half wave lengths long (with the exception of antenna No. 8).

The defendant's antenna wires in Nos. 1, 5 and 7 are approximately 6¼ wave lengths long, in Nos. 2 (original), 3 (original), 4, 6, 8 and 11, they are approximately 7¾ wave lengths long and in No. 10 they are approximately 7¼ wave lengths long.

Plaintiff contends that the Third Carter patent is the final development of the structure disclosed in the two Lindenblad patents in suit and it is alleged that the details of defendant's antennas come nearer to the Third Carter patent than to any other patents in suit. Let us now compare defendant's practices with the teachings of the Third Carter patent in suit.

The teachings of the Third Carter patent in suit in so far as the length of the antenna wires is concerned are the same as those of the two Lindenblad patents in suit.

The description and claims of the Third Carter patent in suit as originally filed and as they stood until August 1934, that is, subsequent to the commencement of this action, dealt only with antenna wires a plurality of half wave lengths long. Claim 1, originally numbered 5, defined the length of the conductors as

[fol. 1376] *"substantially a plurality of half wave lengths long."*

and was amended August 4th, 1934 to read:

"of a length including substantially a plurality of half wave lengths".

The original language covered only antenna wires a plurality of half wave lengths long, but by the broadening amendment of August, 1934, it included all antennas irrespective of their lengths as long as they were at least one wave length long.

In the same amendment the same change was made in claims 6, 7, 8, 9, 10, 25, 31, 32, 33, 34, 39, 40, 43, 44, 45, 46, 47, 48, 49 and 50. Claims in suit 1, 2, 3, 4, 28, 34, 35, 36 and 38 were so amended. And the specification was amended as hereinbefore quoted.

The specification as filed and as it stood at the time of the commencement of the present action did not contain any such language as appeared in the amendment and the claims as they then stood would have excluded defendant's antennas.

I do not agree with plaintiff's contention that the original specification warranted such extension of Carter's disclosure.

After the refusal of the amendment of July 16th, 1934, which included the amendment to the specification hereinbefore quoted and after an oral interview with the Examiner the specification and claims were amended as hereinbefore quoted by the amendment of August 4th, 1934.

The expansion of the application was improper. DeForest v. General Electric Company, 283 U. S. 664.

[fol. 1377] The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well. Carter throughout the specification dealt with conductors measured in half wave lengths or full wave lengths and did not mention conductors a multiple of a

quarter wave length long or conductors of greater or less than half wave lengths. The two Abraham formulæ are applicable only to wires an exact number of half wave lengths long. It is true that in Fig. 12 of the patent Carter drew a smooth curve which apparently includes all lengths of wire between the half wave lengths but I am convinced that neither Carter's empirical formula nor Fig. 12 make a correct showing of what happens when the wires are other than exact multiples of half wave lengths.

Another statement of the specification which plaintiff contends indicates that Carter had in mind antenna lengths which were not integral multiples of half wave lengths refers to

"open-ended wires of any finite length" (p. 1, ll. 29-34),

and does not refer to wires an odd or an even number of half wave lengths long.

Even this passage was added in the amendment of May 2, 1934, and after the commencement of this action.

Before all of the amendments were offered complete and detailed information of defendant's antenna systems was obtained by the plaintiff through litigation previously instituted on the first four patents in suit and by those amendments the plaintiff attempted to mold the third Carter [fol. 1378] patent both as to disclosure and claims, to cover defendant's antenna systems.

This could not lawfully be done. Lopulco Systems, Inc., et al. v. Bonnot Co., et al., 24 Fed. (2d) 510.

As I have hereinbefore stated, defendant's V antennas radiate at an angle to their planes and to their bisectors, and this is contrary to Carter's teachings. The Third Carter patent in suit deals only with horizontal radiation from an antenna in the plane of the wires and the bisector of the angle. There is no illustration of ground or its effect in the patent in suit. This is true even though in Fig. 7 of the patent in suit the legend appears:

"Power Distribution
Vertical Plane
Ground Effect Neglected"

This casual reference to ground does not show that Carter recognized ground effect, as no mention is made thereof anywhere in the specification nor is there any explanation

therein of what was meant by the legend. In any event the casual reference to "ground" contained in Fig. 7 is with reference to power distribution in the vertical plane and with that this litigation is not concerned. Fig. 6 of the patent in suit makes no reference to ground effect, and that relates to power distribution in the horizontal plane and with that this litigation is specifically concerned. I am convinced that the ground effect is without significance with respect to the invention purported to be shown, described and claimed in the Third Carter patent in suit.

[fol. 1379] To distinguish his invention from the Second Lindenblad patent in suit Carter amended his claims, and added new claims.

The Lindenblad patent does not show the relation between the angle and exact length of the antenna as Carter teaches, and in the claims as amended he defines the precise relation between the angle and the length of the antenna. The defendant does not use the precise relation of the Carter patent, and, in view of the Lindenblad patent, Carter could not obtain claims to cover a range of angles. All of defendant's antennas differ from the angle specified by Carter, and while the difference is not great, it is as great as the difference between Bruce (of the prior art) and Carter. If defendant's antenna No. 8, where the angle is differed 10% from Carter, infringes, then Lindenblad anticipates.

Regardless of the validity of the patent, the Third Carter patent in suit is not infringed.

Neither time nor space warranted a detailed consideration in this opinion of each of the contentions of the plaintiff, but they have all received consideration and I have stated my conclusions.

There are, however, certain contentions of plaintiff which I will briefly consider.

Defendant did not copy the antennas and instrumentalities of the patents in suit as contended by plaintiff, as all of the patents in suit, with the exception of the First Carter patent, issued subsequent to the erection of the defendant's antennas charged to infringe, and as I have found with respect to the First Carter patent defendant does not infringe.

[fol. 1380] None of the patents in suit are pioneer patents, as contended by plaintiff, and the record does not show that they have been employed by anyone; even the plain-

tiff's own commercial structures do not follow the teachings or employ the instrumentalities shown, described or claimed in any of the patents in suit, as I have interpreted the same. Therefore the patents in suit are not entitled to a construction of any broader scope than is clearly required to be given. Dernell Potato Products Co. v. Snelling, 38 Fed. (2d) 788-789; Stewart-Warner Corporation v. Jiffy Lubricator Co., 81 Fed. (2d) 786, 793.

Plaintiff makes a point that defendant offered no proof that defendant's antennas were the result of independent investigation and development by defendant, but in view of defendant's contention as to the patents in suit such proof would not be expected; the fact is, however, that defendant's systems are radically different from the patents in suit, in structure, principle of operation and instrumentalities, and were designed and constructed to secure and did secure greater radiation, by reason of such difference, than could be obtained by the patents in suit.

Plaintiff contends with reference to the Third Carter Patent in suit that the invention was of an antenna not a formula, but, even though that be so, the invention was of an antenna, the proper angle between the antenna wires constituting the legs of the V of which was to be determined by the formula supplied.

None of the claims in suit of any of the patents in suit are infringed by any of the antennas or antenna systems [fol. 1381] of the defendant charged in this suit to infringe.

A decree may be entered in favor of the defendant against the plaintiff dismissing the bill of complaint herein with costs.

Settle decree on notice.

Submit proposed findings of fact and conclusions of law in accordance with this opinion, for the assistance of the Court, as provided by the Rule 70½ of the Equity Rules and Rule 11 of the Equity Rules of this Court.

Marcus B. Campbell, U. S. D. J.

In United States District Court, Eastern District of New York

[Title omitted]

Stipulation re Findings and Conclusions

It is Hereby Stipulated by and between counsel for the parties hereto that the opinion of the Court rendered in this cause on October 14, 1936, be accepted as the findings of fact and the conclusions of law in the cause and in com-
[fol. 1382] pliance with the provisions of Equity Rule 70½ and Rule 11 of the Equity Rules of this Court.

Sheffield & Betts, Attorneys for Plaintiff. Darby & Darby, Attorneys for Defendant.

Dated, New York, N. Y., December 29, 1936.

In United States District Court, Eastern District of New York

Equity. #7234

Radio Corporation of America, Plaintiff,

vs.

Mackay Radio and Telegraph Company, Inc., Defendant

Final Decree

The above cause came on to be heard upon the pleadings and evidence herein, and upon briefs and arguments by counsel for the respective parties, and thereupon, upon consideration thereof, a stipulation having been filed that the findings of the Court as set forth in its opinion shall be accepted as in sufficient compliance with Rule 70½ of the Equity Rules and Rule 11 of the Equity Rules of this Court
[fol. 1383] requiring findings of fact and conclusions of law to be filed in said cause, it is

Ordered, Adjudged and Decreed:

1. That the bill of complaint herein, as well as the supplemental bill, be dismissed for want of equity.

2. That defendant recover from plaintiff its costs in the sum of Three Thousand Dollars ($3,000), for which judgment shall be entered in favor of said defendant.

Dated, December 30, 1936.

Marcus B. Campbell, U. S. D. J.

Dated Brooklyn, N. Y., December 29, 1936.

Approved as to form—

Sheffield & Betts, Attorneys for Plaintiff. Darby & Darby, Attorneys for Defendant.

[fol. 1384] In United States District Court, Eastern District of New York

[Title omitted]

Petition for Appeal

The plaintiff, Radio Corporation of America, feeling itself aggrieved by the Final Decree made and entered in the above entitled cause on the 30th day of December, 1936, does hereby appeal to the United States Circuit Court of Appeals for the Second Circuit from the said Decree, for the reasons set forth in the Assignment of Errors filed herewith, and it prays its appeal be allowed and citation issued as provided by law, and that a transcript of the record, proceedings and papers upon which said Decree was made, duly authenticated, be sent to the said United States Circuit Court of Appeals for the Second Circuit.

Dated, New York, N. Y., March 26th, 1937.

Sheffield & Betts, Solicitors for Plaintiff, Office and P. O. Address, 80 Maiden Lane, New York, N. Y.

[fol. 1385] Order Allowing Appeal

The foregoing Petition for Appeal is hereby allowed, and the plaintiff's bond or undertaking for costs on appeal is fixed at the sum of Two Hundred and Fifty Dollars ($250.00).

Dated, Brooklyn, N. Y., March 27th, 1937.

Marcus B. Campbell, U. S. D. J.

IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ASSIGNMENT OF ERRORS

Now Comes Radio Corporation of America, the plaintiff, by Sheffield & Betts, its solicitors, and, in connection with its petition for appeal, says that in the record of proceedings and in the Final Decree made and entered in the above cause on the 30th day of December, 1936, the Court erred:

1. In dismissing the Bill of Complaint herein.

2. In dismissing the Supplemental Bill of Complaint herein.

[fol. 1386] 3. In not granting the prayers of the Bill as to the Lindenblad Letters Patent No. 1,927,522, in suit.

4. In not granting the prayers of the Supplemental Bill as to the Carter Letters Patent No. 1,974,387, in suit.

5. In holding that claims 9, 10, 19, and 23 of the said Lindenblad Letters Patent have not been infringed by defendant's V antenna systems.

6. In not holding that claims 9, 10, 19, and 23 of the said Lindenblad Letters Patent have been infringed by defendant's V antenna systems.

7. In holding that claims, 1, 2, 3, 4, 10, 12, 15, 16, 28, 34, 35, 36, 38, and 40 of the said Carter Letters Patent have not been infringed by defendant's V antenna systems.

8. In not holding that claims 1, 2, 3, 4, 10, 12, 15, 16, 28, 34, 35, 36, 38, and 40 of the said Carter Letters Patent have been infringed by defendant's V antenna systems.

9. In holding that the said two Letters Patent in suit are restricted to the use of radiator wires an integral number of half wave lengths long.

10. In holding that in substance the said two Letters Patent present merely theoretical applications of antenna wires in free space, and in holding that ground effect not only is not contemplated by either of said Letters Patent, but is contradictory to the description and claims thereof.

[fol. 1387] 11. In holding that the said Lindenblad Letters Patent is restricted to a traveling wave antenna.

12. In holding that a mathematical formula was advanced as the invention of the said Carter Letters Patent, and in holding that said mathematical formula had been used by engineers for determining the identical angle between radiating wires of a directional antenna for which it was employed by Carter.

13. In holding that plaintiff, by amendment to the application for said Carter Letters Patent, improperly molded the said Letters Patent, either as to the disclosure or claims, to cover defendant's V antenna systems.

14. In holding that defendant's V antenna systems are radically different from those of said Letters Patent, in structure, principle of operation, and instrumentalities, and that they were designed and constructed to secure, and did secure, greater radiation by reason of such difference, than could be obtained by the structures of said Letters Patent, and in not holding that the V antennas described in the said Carter Letters Patent and the V antennas used by defendant, inevitably operate and function in the same way.

15. In holding that defendant deliberately and intentionally propagates its main lobe of radiation at an angle to the plane of the wires, and in holding that there is any departure by defendant from the teachings of the said Letters Patent in that respect.

[fol. 1388] 16. In holding that defendant's V antennas do not employ the angle taught by the said Carter Letters Patent.

17. In holding that there is no evidence in this case that the defendant, or anyone else, has adopted, or practically used, the antennas described in said two Letters Patent.

18. In not holding that the said Lindenblad Letters Patent described the first directive antenna in the art formed by a pair of long straight wires arranged in a common plane at an acute angle to each other and fed in phase opposition at their adjacent ends.

19. In not holding that the said Carter Letters Patent constituted the first disclosure in the art of directional radio communication of an antenna comprising a pair of simple

long straight wires arranged in horizontal V-formation, the wires being fed in phase opposition at their adjacent ends, the wires being of the length and arranged at the angle effective to produce maximum radiation in the direction of the bisector of the angle of said wires.

Wherefore plaintiff prays that the aforesaid Final Decree of the United States District Court for the Eastern District of New York may be reversed to the extent that plaintiff is appealing therefrom.

Dated, New York, N. Y., March 26th, 1937.

Sheffield & Betts, Solicitors for Plaintiff.

[fols. 1389-1390] Bond on appeal for $250.00 omitted in printing.

[fol. 1391] Citation, in usual form, omitted in printing.

[fol. 1392] In United States District Court

Statement re Stipulations and Orders Extending Time

Stipulations and orders were entered and filed extending the time for filing the transcript of record in this suit in the United States Circuit Court of Appeals for the Second Circuit and the time for securing the approval and filing the statement of evidence and praecipe to be included in said transcript of record to June 25, 1937, to August 25, 1937, to September 25, 1937, and to October 25, 1937, respectively.

[fol. 1393] In United States District Court, Eastern District of New York

[Title omitted]

Stipulation and Order Extending Time

It is Hereby Stipulated by and between the solicitors for the respective parties that the time for filing the transcript of record in the above entitled suit in the United States Cir-

cuit Court of Appeals for the Second Circuit on appeal by plaintiff, be extended to November 26, 1937.

Dated, New York, N. Y., October 18, 1937.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

It is so ordered this 19th day of October, 1937.

Percy G. B. Gilkes, Clerk.

[fol. 1394] In United States District Court, Eastern District of New York

[Title omitted]

Stipulated Praecipe for Transcript of Record

To the Clerk of the United States District Court for the Eastern District of New York:

It is Hereby Stipulated and Agreed by and between the parties hereto, through their respective solicitors, subject to the approval of the Court, that the printed transcript of record on appeal should conform to the following terms of this praecipe and contain the following:

1. Bill of Complaint.
2. Defendant's answer.
3. Motion for Leave to File Supplemental Bill of Complaint, Order thereon, and Supplemental Bill of Complaint.
4. Defendant's Answer to Supplemental Bill of Complaint.
5. The narrative and condensed statement of evidence of the witnesses at the trial as stipulated and agreed on by the [fol. 1395] solicitors for the parties and as approved by the Court on the 8th day of October, 1937.
6. Stipulation and Order approving the narrative statement of evidence.
7. The following exhibits:

Documentary:

Plaintiff's—1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15 (only the side and end elevations [second row of diagram] and the plan view [third row] of the antenna, together with the printed matter at the bottom), 16, 17, 18, 19 (sections H, L,

and title only), 20, 21, 22 (cover, pages 2, 4 to 6 inclusive, and 20 to 27 inclusive), 23a, 24, 27, 28, 30, 31, 32, 36, 37, 38, 39, 40, 41, 42, 43 (and stipulation of April 21, 1936), 44, 45, 46, 47, 48, 51, 52, 53, 54, 57 and 58.

In lieu of Plaintiff's Exhibit 55, a statement reading as follows:

"Plaintiff's Exhibit 55 is a certified copy of an application for Letters Patent of the United States for 'Improvement in Horizontal Vee-Type Antenna', filed by or on behalf of Edmond Bruce on February 3, 1931, bearing Serial No. 513,063. The British patent No. 392,201, issued to assignees of Edmond Bruce (constituting Plaintiff's Exhibit 41 and reproduced above), was issued upon an application filed in Great Britain under the Convention and corresponding to the above-mentioned U. S. application Ser. No. 513,063 (Plaintiff's Exhibit 55)."

[fol. 1396] Defendant's—A, F, G, S, T, U, V (translations only of Abraham 1898 and 1901 articles, Bergmann article and the Bontsch-Bruewitsch article), W, X, Y, Z, AA (as to Bethenod French patents Nos. 596,737 and 625,293, the Levy French patent No. 593,570 and the patent of addition No. 30,798, and the Takagishi Japanese patent, include only the translations and drawings), BB, CC, DD, FF, GG, HH, JJ, KK, LL, MM, NN, OO (title page and pages 675 and 681 only), PP, QQ, UU, and VV.

Physical:

Plaintiff's—29.

8. Opinion of Marcus B. Campbell, District Judge.

9. Stipulation of December 29, 1936, with respect to findings of fact and conclusions of law.

10. Final Decree dated December 30, 1936.

11. Petition for appeal and Order allowing appeal.

12. Plaintiff's assignment of errors.

13. Undertaking for costs filed by plaintiff (omitting justification of Surety Company and affidavit).

14. Citation.

15. Stipulations and Orders extending time to file transcript of record, obtaining approval and filing of state-
[fol. 1397] ment of evidence and praecipe (or statement covering such Stipulations and Orders).

16. This Praecipe and Order approving same.
17. Stipulation as to printed record and Order thereon.
18. Clerk's certificate.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

Dated, New York, N. Y., October 9, 1937.

It is so ordered this 11th day of October, 1937.

Marcus B. Campbell, U. S. D. J.

[fol. 1397a] In United States District Court, Eastern District of New York

[Title omitted]

Stipulation and Order Extending Time

It is Hereby Stipulated by and between the solicitors for the respective parties that the time for filing the transcript of record in the above entitled suit in the United States Circuit Court of Appeals for the Second Circuit on appeal by plaintiff, be extended to December 27, 1937.

Dated, New York, N. Y., November 18, 1937.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

It is so ordered this 19th day of November, 1937.

Percy G. B. Gilkes, Clerk.

[fol. 1397b] In United States District Court, Eastern District of New York

[Title omitted]

Stipulation and Order Extending Time

It is Hereby Stipulated by and between the solicitors for the respective parties that the time for filing the transcript of record in the above entitled suit in the United States Cir-

cuit Court of Appeals for the Second Circuit on appeal by plaintiff, be extended to February 4, 1938.

Dated, New York, N. Y., December 15, 1937.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

It is so ordered this 20th day of December, 1937.

Percy G. B. Gilkes, Clerk.

[fol. 1398] In United States District Court, Eastern District of New York

[Title omitted]

Stipulation and Order as to Record

It is Hereby Stipulated and Agreed, that the foregoing (in 2 Vols.) is a true copy of the transcript of the record of the said District Court in the above entitled matter as agreed on by the parties.

Dated, Feb. 1st, 1938.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

On reading the foregoing consent of the solicitors for the respective parties herein, it is

Ordered that the foregoing printed record be filed in lieu of the original papers for the purpose of certifying a record on appeal.

Dated, Feb. 2nd, 1938.

Marcus B. Campbell, U. S. D. J.

[fol. 1399] Clerk's certificate to foregoing transcript omitted in printing.

1400

[fol. 1400] UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT

RADIO CORPORATION OF AMERICA, Plaintiff-Appellant

against

MACKAY RADIO AND TELEGRAPH COMPANY, INC., Defendant-Appellee

Before Manton, L. Hand and Swan, Circuit Judges

Appeal from the District Court for the Eastern District of New York. Suit for infringement of patents. Decree for defendant; plaintiff appeals. Decree modified.

Sheffeld & Betts, Jo. Baily Brown, Abel E. Blackmar, Jr., Harry Tunick, of Counsel for Appellant.

Darby & Darby, Attorneys for Appellee. Hugh M. Morris, Samuel E. Darby, Jr., Paul Kolisch, Roy C. Hopgood, E. D. Phinney, of Counsel.

MANTON, Circuit Judge:

This appeal involves the validity and infringement of the Lindenblad patent No. 1,927,522, granted September 19, 1933, on an application filed December 24, 1928, and the Carter patent No. 1,974,387, granted September 18, 1934, on an application filed June 11, 1930. Both are for short wave directional antennas composed of a pair or pairs of long wires, the two wires of each pair being placed at an [fol. 1401] angle to each other to form a V. Claims 9, 10, 19 and 23 of the Lindenblad patent and Claims 15 and 16 of the Carter patent are in issue.

Directive radio transmission is of commercial importance where communication is regularly carried on between two or more fixed stations. The advantage of highly directive systems for point to point communication is that interference with other systems is reduced and for a given amount of energy sent out by the transmitting station, a stronger or more reliable signal is heard at the desired receiving point. When radio waves are directed or concentrated upon a given receiver, freedom from interference follows. If the transmitter in New York concentrates its radio waves upon a receiver in a city in Central Europe, no waves or only feeble waves will travel in other directions and as a result other

receiving stations to the north, west or south points will not be subjected to interference. If the New York station transmits using a highly directive antenna (as Carter) which concentrates most of the 360 kilowatts of power into a bundle of rays confined within an angle of 20° or less, there would be substantially the same total power concentrated within 1/18th of the full compass circle or nearly 18 kilowatts compressed into each one degree sector instead of only one kilowatt. Thus, much of the power that would be wasted if the waves were broadcast in all directions may be brought to bear upon a particular receiving station and the intensity of the receiving signal multiplied.

The best antenna to serve these purposes appeared in 1926 as the Marconi beam antenna. It was made up of a complex network composed a large number of short wires. It [fol. 1402] was highly directive and expensive costing about $100,000. to produce. It was difficult to adjust and keep in repair.

Appellant's models B and C were built in 1929. They were built of pairs of long parallel, simple wires which co-operated to give highly directional effects. They were built at a cost of $30,000 and $48,000 and were made under prior Lindenblad patents.

No successful use of any other directional wireless is referred to until antennas made under the patents here to be considered were built. The first step in the directive antenna (made as Model D) under these patents was developed in the invention of Lindenblad. The primary units (like Models B and C) were made of long simple wires and the antenna consisted of two such wires placed at an angle with each other to form a V. Although the V-antenna described by Lindenblad had utility, it was not adapted for commercial use until Carter's improvement had been applied for. This antenna consists of one or more pair of long, straight, unmodified wires placed at a preferred angle; when a simple V is used the antenna is bi-directional. The predominant radiation of radio waves from the antenna is in two directions, the direction determined by the line bisecting the angle between the wires. By the use of two V's properly spaced with respect to each other and fed with current in proper phase relation, unidirectional action is secured. The predominant radiation is in one direction only. The direction of the bisector of the angle between the wires is either forward or backward according to the

connection used. This is the Carter patent. It was an im-
[fol. 1403] provement over the directive antennas which had preceded it. Its cost was $5,000 as against $30,000 for the cheapest previous types. Its directivity was equal to the Marconi beam.

Although the theory of operation of a single wire had been previously developed prior to Lindenblad and Carter, no one had found how the theory could be utilized in the solution of the problem of constructing a highly directive antenna. One of the steps in the development of Carter's patented antenna is set forth in the Lindenblad patent. A long wire V antenna is shown in fig. 2. In the antennas of each of the patents energy is fed into the antenna by transmission line through an impedance matching device, in such manner that the energy fed to one antenna wire is of opposite phase to that fed to the other wire, that is, when the potential at any point on one wire is positive, that of the corresponding point on the other is negative and vice versa.

Lindenblad says that the current on the antenna wires may be in the form of standing waves, or "as a refinement" and "a further object of my invention" is in the form of travelling waves. He says that with travelling waves the sideways radiation is less than with standing waves, but the reduction of radiation in undesired directions may be obtained by other means.

Lindenblad stated nothing as to the advantages of any specific angle between the wires of his V-antenna and as to any relation between preferred angle, wire length and wave length. He said that the spacing between the ends of the wires "while variable" over a long range should be in the neighborhood of a fifth of the length which, regardless of
[fol. 1404] wave lengths and wire lengths, means an angle under 12° between the wires. The wire length suggested is of the order of five or ten waves long. Carter taught 12° is not the most desirable angle for a V-antenna having wires of these lengths. He developed the theory of long wire V-antennas and taught how to construct them so as to secure maximum directivity by co-ordinating the angle wire length and wave length. He found that the use of a preferred angle for any given wire length and wave length gave an antenna which was equal or superior in directivity to any known antenna and far less costly to erect. Carter described multiple V-antennas both for preventing undesired high angle

radiation, for securing further concentration in the horizontal or compass direction and for securing unidirectivity.

Claim 10 of the Lindenblad patent is typical and will be selected in determining the question of infringement. It reads:

"In combination, a transmission line, and an antenna extending longitudinally in the direction of desired radiant action connected thereto comprising a pair of open ended conductors of the order of magnitude of a number of wave lengths long which are widely spaced at the ends remote from the transmission line and energized with energy of opposite polarity, and spaced at the spacing of the transmission line at their junction therewith."

The inventor intended to get rid of standing waves and he was to accomplish it by lengthening his antenna which eliminated reflection in the antenna. It, however, made the space between the conductors too long to be practicable. His figs. 3 and 4 show the conductors bend back and forth [fol. 1405] across each other and these figures were for travelling waves only. Fig. 2 was a standing wave antenna and would need an impedance matching device unless the transmission line was very short. He expected some standing waves and thought to improve on the di-pole.

Carter's Claim 15 reads:

"An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twive $50.9\left(\frac{1}{\lambda}\right)-0.513$ degrees, 1 being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length."

Claim 16 differs from Claim 15 primarily in calling for "a similar parallel pair of conductors spaced at odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors."

The appellee's V-antenna wires are relatively long. The angles used by it are all substantially the angles determined by the formula set forth in Carter's Claim 15.

Appellee constructs its V-antenas (Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11) utilizing in most instances substantially the exact angle specified by Carter, and places them upon poles 80 feet high and secured antennas that were effective in the identical directions that Carter described. Structurally the antennas are Carter's and secure the same results as he describes, that is, concentration of radiation on the distant receiving antenna, simplicity and efficiency. They are used to obtain the results Carter sought. The angle between each [fol. 1406] wire of appellee's antenna No. 2 and the bisector of the angle between them is 17.5°. Carter's formula and curve call for an angle of approximately 17.8° for wires of this length. The compass bearing of the bisector of this antenna is N. 49.75° E. This is referred to as the directivity of the antenna. This particular antenna is shown to have been used for communication between Vienna and Sayville, L. I., the direction of which is N. 49.74° E. from Sayville, which is substantially that of the bisector.

No. 1 is representative of appellee's double V antennas and it too is established to infringe. Indeed, the difference in each is trifling except No. 8 where there is a divergence of about 10%. 22½° as against 25°. No 10 has a departure of 5% away from the prescribed angle. These we think are substantially the same as the empirical angle. By appropriating Carter's idea, the substance of his discovery was taken and there is infringement.

Lindenblad in his V-shaped antenna greatly reenforced transmission. His angle was a little less than 12° and was practicable. Claim 10 required widely spaced conductors but the appellee used an angle never less than 17.5 and cannot be charged with infringement if the claim be limited as it should. It cannot be read more broadly for it appears that on several angles such an antenna will not operate. The problem was how to proportion the conductor length to the angle and this had to be worked out by trial. The patent gave no direction to the art, but it did give a suggestion. That is insufficient to cover the operations of the appellee and it may not be held to have infringed the Lindenblad patent.

[fol. 1407] It is argued that the patent is limited to antennas utilizing the predominant radiation which goes out exactly in the plane of the wires to the exclusion of that which goes at some small angle to that plane. When the

antenna is placed over ground on 80 foot poles, the presence of the ground affects radiation in certain ways but not so far as the directivity in compass direction is concerned. The unavoidable effects in the presence of ground are that radiation that has left the antenna in the exact mathematical plane parallel to the earth is, at a distance from the antenna, cancelled by a radiation that left the antenna at a slight downward angle and been reflected upward from the ground. Radiation which has left in a small upward angle, is reenforced by radiation that left at a similar downward angle and has been reflected from the earth's surface. These effects always occur when short wave antennas are placed as both appellant and appellee place theirs, that is, not far above the surface of the ground.

Cancellation of horizontal radiation does not destroy the effectiveness of the antenna as a source of signals for a distant receiving station. Long distance short wave transmission is not carried on by means of signals transmittted horizontally along the surface of the earth; the signals that reach a distant receiving antenna are those which have left the transmitting antenna at a small upward angle and been deflected back to earth by a portion of the upper atmosphere that reflects radio waves due to the fact that it is conductive [fol. 1408] because of ionization. The main consideration is that Carter described a practical directive antenna which is of great commercial utility when used just as he said it was to be used. He was concerned with antennas which would concentrate the radiation in certain compass directions. These antenna structures are used by both appellant and appellee.

It is next argued that the patent is limited to antennas, the wires of which are an integral number of half waves long. Most of appellee's antennas do not use wires that are of integral number of half wave lengths but that does not avoid infringement. Carter's application stated that the invention was applicable to wires of any finite length. His original application included the empirical formula and the curve of that formula is shown and described. Appellee's argument is based upon the limited application of the prior art Abraham formulas. The effect of this argument is to show that as to wires which are not an integral number of half waves long, the recognition that there was for such wires an angle of predominant radiation was not

obvious but was covered by Carter. Carter found that interpolation between these lengths was sufficiently accurate for practical purposes and disclosed the angles to use for V-antennas using wires of intermediate lengths. Appellee followed this disclosure and accomplished the results set forth by Carter.

Another argument advanced is that the patent is limited to antennas using the exact angle recommended by Carter. The argument proceeds that appellee's V-antennas utilize a slightly smaller angle than that recommended by Carter, with the result that the upwardly tilted radiation is still [fol.1409] more augmented by ground effect. But nine out of appellee's eleven V-antennas were found to be substantially the exact angle recommended by Carter and the other two were appreciably smaller.

We do not find that the prior art anticipated Carter's invention. The Bethenod French patent No. 596.737 was an old type of long wave antenna—two horizontal networks of wires one placed above the other, the two being fed in phase opposition. It fails to disclose the Carter invention for the latter was not merely for the use of long wires in antenna system but involved placing the wires in the form of a V and at the preferred angle disclosed. Bethenod failed to disclose either of these arrangements. His parallel net works taught nothing to the art in the solution of the problem here involved. It is insufficient to invalidate this patent disclosing a meritorious invention. Babcock & Wilcox Co. v. Springfield Co., 16 Fed. 2, 964 (C. C. A. 2); Electro-Bleaching Gas. Co. v. Paradon Engineering Co., 12 Fed. 2, 511 (C. C. A. 2).

The Bethenod French Patent No. 625,293 discloses a single wire antenna. The novelty of this arrangement is in the feed system but not in the antenna. Even though it disclosed an electrically long wire it does not disclose the two wire V-antennas of the Carter patent. He shows a single wire which he says may be placed at an angle with respect to the ground and appellee argues that this single wire with its image in the ground constitutes a pair of wires. This is referred to as the image theory. But the testimony of the experts clearly refutes this theory. The image in the ground of an actual wire above the ground is [fol. 1410] purely a theoretical consideration. After an antenna has been designed, the image theory may be used to analyze the ideal effect of ground upon its radiation.

But it is quite different from taking a prior antenna and its image and attempting to use those as a new antenna. The record discloses no one has ever attempted to do that. Moreover, the actual wire and its image is never equivalent to a two-wire antenna for a two-wire antenna necessarily is more than twice as directive as a single wire antenna including its image.

The French patent to Levy No. 593,570 (and the addition thereto of No. 30,798) shows two networks each composed of three electrically short wires, the network being fed in phase opposition. Levy's wires were short and he failed to appreciate any advantage in the use of long wires which constitute the fundamental antenna unit of Carter. He, like Bethenod, is indefinite as to the obtaining of a directive action with his antenna. He does not tell what type of directivity may be secured or how any desired kind of directivity may be secured. He uses parallel wires in each of his networks and failed to make any provision with respect to feeding the individual wires in such a way that each network as a whole will radiate substantially as though it were a single wire. The radiation of such networks is uncertain because the phasing and relative position of the wires are not definite.

The alleged prior invention of Bruce does not anticipate. He had experience in the study of short wave antenna problems and did seem in 1926 to have thoughts of a directive antenna composed of a pair of simple straight long wires [fol. 1411] arranged in common plane, but he failed to appreciate the possibilities of a long wire V-antenna nor did he recognize the possibilities of such construction. It was after the patents in suit had become known that he proceeded to obtain his result. His experiments previous to the work of Lindenblad and Carter were no more than abandoned efforts. Such abandoned experiments even though they utilized the exact patented structure, which Bruce did not, have been held insufficient to invalidate a patent. Coffin v. Ogden, 18 Wall. 120; Deering v. Winona Harvester Wks., 155 U. S. 286; The Corn-Planter Patent, 23 Wall. 181.

The Abraham articles of 1898 and 1901 with the formula suggested, although 30 years old, had never been utilized. From that time was the entire period of the development of the radio art. While his formulas unquestionably had useful scientific interest to radio engineers, they failed to

teach how to construct a directive antenna. Nothing in them suggests the inventions of Carter.

The problem solved here was of long standing and it was an eminently successful solution. Critical examination of prior patents and uses finds nothing invalidating the Carter invention and it shows a substantial accomplishment.

The decree will be modified holding the Lindenblad patent not infringed and the Carter patent valid and infringed.

Decree modified accordingly.

[fol. 1412] UNITED STATES CIRCUIT COURT OF APPEALS, SECOND CIRCUIT

At a stated term of the United States Circuit Court of Appeals, in and for the Second Circuit, held at the United States Court House, in the City of New York, on the 9th day of May, one thousand nine hundred and thirty-eight.

Present: Hon. Martin T. Manton, Hon. Learned Hand, Hon. Thomas W. Swan, Circuit Judges.

RADIO CORPORATION OF AMERICA, Plaintiff-Appellant,

vs.

MACKAY RADIO AND TELEGRAPH COMPANY, INC., Defendant-Appellee.

Appeal from the District Court of the United States for the Eastern District of New York.

This cause came on to be heard on the transcript of record from the District Court of the United States for the Eastern District of New York, and was argued by counsel.

On Consideration Whereof, it is now hereby ordered, adjudged, and decreed that the decree of said District Court be and it hereby is modified in accordance with the opinion of this Court.

It is further ordered that a mandate issue to the said District Court in accordance with this decree.

Wm. Parkin, Clerk.

[fol. 1413] Endorsed: United States Circuit Court of Appeals, Second Circuit. Radio Corporation of America vs. Mackay Radio and Telegraph Company, Inc. Order for

Mandate. United States Circuit Court of Appeals, Second Circuit. Filed May 9, 1938. William Parkin, Clerk.

[fol. 1414] UNITED STATES OF AMERICA,
Southern District of New York:

I, William Parkin, Clerk of the United States Circuit Court of Appeals for the Second Circuit, do hereby certify that the foregoing pages, numbered from 1 to 1413, inclusive, in 2 volumes, contain a true and complete transcript of the record and proceedings had in said Court, in the case of Radio Corporation of America, Plaintiff-Appellant, against Mackay Radio and Telegraph Company, Inc, Defendant-Appellee, as the same remain of record and on file in my office.

In Testimony Whereof, I have caused the seal of the said Court to be hereunto affixed, at the City of New York, in the Southern District of New York, in the Second Circuit, this twenty-first day of May, in the year of our Lord one thousand nine hundred and thirty-eight, and of the Independence of the said United States the one hundred and sixty-second.

Wm. Parkin, Clerk. (Seal United States Circuit Court of Appeals, Second Circuit.)

[fol.1415] SUPREME COURT OF THE UNITED STATES

ORDER ALLOWING CERTIORARI—Filed October 10, 1938

The petition herein for a writ of certiorari to the United States Circuit Court of Appeals for the Second Circuit is granted. And it is further ordered that the duly certified copy of the transcript of the proceedings below which accompanied the petition shall be treated as though filed in response to such writ.

Endorsed on cover: Enter Samuel E. Darby, Jr. File No. 42,612. U. S. Circuit Court of Appeals, Second Circuit. Term No. 127. Mackay Radio and Telegraph Company, Inc., petitioner, vs. Radio Corporation of America. Petition for a writ of certiorari and exhibit thereto. Filed June 17, 1938. Term No. 127, O. T., 1938.

FILE COPY

Office - Supreme Court, U. S.
FILED
JUN 17 1938
CHARLES ELMORE CROPLEY
CLERK

IN THE

Supreme Court of the United States

October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

PETITION OF MACKAY RADIO AND TELEGRAPH COMPANY, INC., FOR A WRIT OF CERTIORARI TO THE CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT, AND BRIEF IN SUPPORT THEREOF.

SAMUEL E. DARBY, JR.,
Attorney for Petitioner.

HUGH M. MORRIS,
PAUL KOLISCH,
ROY C. HOPGOOD,
E. D. PHINNEY,
of Counsel.

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IN THE

Supreme Court of the United States

October Term, 1938

No. . . .

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,

Petitioner,

vs.

RADIO CORPORATION OF AMERICA,

Respondent.

PETITION OF MACKAY RADIO AND TELEGRAPH COMPANY, INC., FOR A WRIT OF CERTIORARI TO THE CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT.

To the Honorable, The Chief Justice, and Associate Justices of the Supreme Court of the United States:

Your petitioner, Mackay Radio and Telegraph Company, Inc., respectfully prays for a writ of certiorari to the Circuit Court of Appeals for the Second Circuit to review the judgment of that Court entered on May 2, 1938. A transcript of the record in the case, including the proceedings in said Circuit Court of Appeals, is furnished herewith in accordance with the Rules of this Court.

Summary and Short Statement of the Matter Involved.

1. This is a patent infringement suit brought by respondent, Radio Corporation of America, on patents included in the patent pool which forms the so-called "Radio Trust".*

2. Petitioner is a public service company engaged, with associated companies, in the radio telegraph transmission of public messages between the principal cities of the United States and foreign countries. *In this respect petitioner and its associated companies constitute the only competition to the world wide public service operations of respondent, Radio Corporation of America, and its subsidiary RCA-Communications.*

3. The present suit is directed to the effort on the part of respondent to eliminate competition in its public service operations, *i. e.*, to completely eliminate competition in public radio communication between the principal cities of the United States, and between the United States and the other nations of the world.

4. Respondent initially filed suit charging petitioner with infringement of four patents having to do with an-

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* See *Lord et al.* v. *Radio Corporation of America,* 24 Fed. (2) 565;

Same v. *Same,* 28 Fed. (2) 257;

Same v. *Same,* 35 Fed. (2) 962;

Same v. *Same,* 47 Fed. (2) 606.

Stanley Company of America v. *American Telephone & Telegraph Co., General Talking Pictures Corp.* v. *American Telephone & Telegraph Co., Duovac Radio Corporation* v. *American Telephone & Telegraph Co.,* 4 Fed. Supp. 80.

Same v. *Same,* 18 Fed. Supp. 650.

tenna structures and their operation. At the time the bill was filed respondent had pending in the Patent Office, in the name of one Carter, an application for a fifth patent for an antenna structure. Subsequent to petitioner's answer in the suit, and after receiving particulars as to the structure and operation of petitioner's antennas, respondent completely altered the statement and claim of invention in the pending Carter application so as to attempt to include therewithin petitioner's antenna structures.*

5. Thereafter the Carter patent issued (referred to in the litigation as the "Third Carter patent") and a supplemental bill of complaint was filed charging infringement thereof. The suits were consolidated and the parties proceeded to trial on all five patents before Judge CAMPBELL in the Eastern District of New York.

6. After a trial which lasted nearly a month, Judge CAMPBELL dismissed the bills of complaint as to all patents, finding as a fact, on the conflicting evidence before him, that petitioner's antennas differed "radically" from all of the patents "in structure, principle of operation and in-

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* The District Court stated in its opinion (Vol. II, p. 1377, fol. 4129):

> "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well."

and (fol. 4131):

> "* * * by those amendments the plaintiff attempted to mould the third Carter patent, both as to disclosure and claims, to cover defendant's antenna systems.
>
> This could not lawfully be done."

strumentalities", and operated on principles not only different from those of the patents, but "contradictory thereto as well".*

7. Respondent acquiesced in the decree of the District Court dismissing the bill of complaint as to three of the patents, but appealed from that decree as to the two antenna patents—Lindenblad 1,927,552 and the Carter patent.

8. The appeal was argued April 8th, 1938. On May 2nd, barely more than three weeks thereafter, the Court of Appeals announced its decision (per Judge MANTON) holding the Carter patent valid and infringed. Thereby it, in effect, reversed every essential finding of fact made by the District

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* The District Court said (Vol. II, p. 1363, fol. 4087):

"The defendant's antennas which are charged with infringement differ *radically* from the inventions claimed in the three antenna patents in suit." (Italics ours.)

Again, the Court said (p. 1364, fol. 4090):

"In substance all of the antenna patents in suit present merely a theoretical application of antenna wires in free space, whereas all of defendant's antennas are intentionally designed to cooperate with ground effect, *which effect is not only not contemplated by any of the patents in suit, but is contradictory to the description and claims thereof.*" (Italics ours.)

The Court also found (p. 1372, fol. 4115):

"Due to the departure from the Carter patent in the respects enumerated and by reason thereof in all of defendant's antennas here charged to infringe, defendant obtains material advantages and increased efficiency in that material increase in radiated power is obtained."

Finally, the Court found (p. 1380, fol. 4139):

"* * * the fact is, however, that *defendant's systems are radically different from the patents in suit, in structure, principle of operation and instrumentalities,* and were designed and constructed to secure and did secure greater radiation, by reason of such difference, than could be obtained by the patents in suit." (Italics ours.)

Court, although the Court of Appeals did not point out any error in such findings of the District Court, or cite any evidence to support its contrary finding. It affirmed the District Court with respect to the Lindenblad patent.

9. The present petition therefore seeks a review of the decision of the Court of Appeals for the Second Circuit only insofar as it holds the Carter Patent No. 1,974,387 valid and infringed by petitioner's antennas, *all of which were erected and fully disclosed to respondent prior to the issuance of the said patent.*

Reasons Relied Upon for the Grant of a Writ of Certiorari.

The discretionary power of this Court is invoked upon the following grounds:

1. The Circuit Court of Appeals for the Second Circuit has sustained a patent of the "Radio Trust" patent pool, thereby vesting in respondent a complete monopoly in the type of antenna structure which respondent asserts is essential to modern, efficient, economical, long distance radio communication. The consequence is that thereby respondent becomes vested with a complete monopoly in public service radio telegraph communication. This is a matter of such great economic and public importance, and so materially affects public interests, as to warrant a review by this Court to test the validity of the basis upon which so vast, far reaching and important a monopoly is based.

2. The Circuit Court of Appeals for the Second Circuit, in holding the Carter patent to be valid and infringed by petitioner's antenna structures, reversed every essential finding of fact made by the District Judge on the conflicting

evidence before him, thus rendering a decision which is untenable and in direct conflict with the doctrine announced by this Court in *Adamson* v. *Gilliland*, 242 U. S. 350, at 353 that—

> "• • • so far as the finding of the Master or Judge who saw the witnesses 'depends upon conflicting testimony or upon the credibility of witnesses, or so far as there is any testimony consistent with the finding, it must be treated as unassailable'."

3. Because of the fact that petitioner and its associated companies constitute the only competition to respondent in the public service field of world wide radio telegraph communication there is no likelihood of the Carter patent being involved in other litigation, with the result that the decision of the Court of Appeals will probably be the only and final decision with respect to the Carter patent, by which respondent seeks to effect and maintain a monopoly in such communications until September 18, 1951, the date of expiration of the patent.

4. Although there is no diversity of opinion between Circuit Courts of Appeals with respect to the Carter patent, the sharp conflict in the conclusions reached by the Trial Judge and by the Court of Appeals, in a case involving subject matter of such great public importance, and of a nature wherein there is no likelihood of the patent ever being litigated again, warrants a review by this Court.

Schribner-Schrott Co. v. *Cleveland Trust Co., Chrysler Corp.*, No. 674, October Term, 1937; certiorari granted May 31, 1938;
The Barber Asphalt Case, 302 U. S. 458;
Paramount Publix Corp. v. *American Tri-Ergon Corp.*, 294 U. S. 464;

Altoona Publix Theatres Inc. v. *American Tri-Ergon Corp.*, 294 U. S. 477;
Carbice Corporation v. *American Patents Development Corp.*, 283 U. S. 27;
DeForest Radio Co. v. *General Electric Co.*, 283 U. S. 664.

5. The Court of Appeals for the Second Circuit has sustained as valid a patent which is invalid because of improper amendment thereof, and because it is completely anticipated by and discloses no patentable invention over the prior published art.

WHEREFORE, your petitioner respectfully prays that a writ of certiorari be issued out of and under the seal of this Court, directed to the United States Circuit Court of Appeals for the Second Judicial Circuit, sitting at New York, New York, commanding such Court to certify and send to this Court, on a day to be designated, a full transcript of the record and all proceedings of the Court of Appeals had in this case, to the end that this case may be reviewed and determined by this Court; that the judgment of the Court of Appeals be reversed; and that petitioner be granted such other and further relief as may seem proper.

SAMUEL E. DARBY, JR.,
Attorney for Petitioner.

HUGH M. MORRIS,
PAUL KOLISCH,
ROY C. HOPGOOD,
E. D. PHINNEY,
of Counsel.

Dated: New York, N. Y.
June 15th, 1938.

BRIEF IN SUPPORT OF PETITION FOR WRIT OF CERTIORARI.

Opinions of the Courts Below.

The opinion of the Circuit Court of Appeals for the Second Circuit is not yet reported, but is found in the printed record Vol. II, page 1400.

The opinion of the District Court is reported in 16 Fed. Supp. 610 (Rec. Vol. II, p. 1345 *et seq.*).

Jurisdiction.

The grounds of jurisdiction are:

1. The date of the judgment to be reviewed is May 2, 1938.

2. The judgment was rendered in a suit in equity brought under the patent statutes to determine the issues of validity and infringement of Letters Patent of invention.

3. The statute under which the jurisdiction is invoked is 240-A of the Judicial Code, 28 U. S. C. 347, as amended by the Act of February 13, 1925.

4. The cases believed to sustain the jurisdiction are:

   Schribner-Schrott Co. v. *Cleveland Trust Co., Chrysler Corp.*, No. 674, October Term, 1937; certiorari granted May 31, 1938;

   The Barber Asphalt case, 302 U. S. 458;

   Paramount Publix Corp. v. *American Tri-Ergon Corp.*, 294 U. S. 464;

   Altoona Publix Theatres Inc. v. *American Tri-Ergon Corp.*, 294 U. S. 477;

Carbice Corp. v. *American Patents Development Corp.*, 283 U. S. 27;
DeForest Radio Co. v. *General Electric Co.*, 283 U. S. 664.

Statement.

The facts are sufficiently stated in the petition.

Specifications of Error.

The errors which petitioner will urge, if the writ of certiorari is allowed, are that the Circuit Court of Appeals for the Second Circuit erred:

1. In sustaining the Carter Patent No. 1,974,387 as valid and infringed.
2. In overruling every essential finding of fact of the District Court with respect to the issues relevant to the Carter patent without authority or reference to the evidence.
3. In failing to affirm the District Court on the facts found by that Court, and established by the record, whereby the Carter Patent No. 1,974,387 is invalid because of unlawful amendment to its statement, description and claim of invention.
4. In failing to affirm the District Court's finding of fact that defendant's antenna structures, charged to infringe, differ "radically * * * in structure * * *, principle of operation, and instrumentalities" from that of the patent, and operate on principles not only different from those of the patent but "contradictory thereto as well".

5. In failing to hold Carter Patent No. 1,974,387 invalid as completely anticipated by and wanting in invention over the prior art.

Summary of Argument.

The points of argument follow the reasons relied upon for the grant of a writ of certiorari, and are stated on pages 5 to 7 of the Petition, as well as in the index hereto. For the sake of brevity they are omitted at this point.

ARGUMENT.

POINT I.

The Court of Appeals has sustained a patent of the Radio Patent Pool, thereby vesting in respondent a monopoly in public service radio telegraph communication.

The Carter patent relates to a V-antenna structure, and is asserted to cover the type of antenna structure possessing the qualities of economy of erection and maintenance, and efficiency of operation, necessary to conduct directive intercity and international radio telegraph communication. The patent is one of those included in the pool of patents of the so-called Radio Trust. It requires but brief statement, and no argument, to point out that the subject of radio telegraph communication is of such importanct as to warrant the careful scrutiny by this Court of the validity of the basis for any monopoly in that field. That is especially so when, as here, it is the public service field of radio telegraph communications that is involved.

While we do not question the propriety of a patent monopoly, we do assert that such a monopoly in a public service utility—*public communications*—is of such magnitude and of such vital importance to the public at large that the validity of the grant upon which it purports to be predicated should be scrutinized by this Court in a review of this case. It is submitted that this is especially so where, as here, there is such sharp conflict between the conclusions and findings of the Trial Judge and of the appellate Court.

POINT II.

The Circuit Court of Appeals for the Second Circuit reversed every essential finding of fact made by the Trial Court on the conflicting evidence before him.

In reaching its decision, resulting in a reversal of the Trial Judge and the holding of validity for the Carter patent as well as the infringement thereof, the Court of Appeals necessarily reversed every essential finding of fact made by the Trial Judge on the conflicting evidence before him. This the Court of Appeals did without pointing out any error on the part of the Trial Judge, and without reference to any authority or evidence to support its conclusions.

Thus, as we have pointed out (see footnote, p. 4), the Trial Judge found that defendant's antennas differed "radically" from the Carter patent "in structure, principle of operation and instrumentalities", and operated on principles not only different from those of the Carter patent, but "contradictory thereto as well". The Court of Appeals swept aside these fact findings without comment, and ar-

rived at a diametrically opposite conclusion without citation of authority or evidence.

Again, the Trial Judge found that by illegal amendment, unsupported by the oath of the inventor, the application for the Carter patent had been altered in the effort to have the patent cover defendant's structures. With respect to this amendment the Court said (Vol. II, p. 1337, fol. 4129):

> "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well."

The Court further said (fol. 4131) that:

> "• • • by those amendments the plaintiff attempted to mould the third Carter patent, both as to disclosure and claims, to cover defendant's antenna systems.
>
> This could not lawfully be done."

The Court of Appeals also swept aside these fact findings of the Trial Judge without citation of evidence or authority.

This complete reversal of all essential fact findings of the Trial Judge, made on conflicting evidence before him, is believed to be in direct conflict with the decision of this Court in *Adamson* v. *Gilliland*, 242 U. S. 350. In that case this Court said (at p. 353):

> "• • • so far as the finding of the Master or Judge who saw the witnesses 'depends upon conflicting testimony or upon the credibility of witnesses, or so far as there is any testimony consistent with the finding, it must be treated as unassailable'."

It is submitted, therefore, that the Court of Appeals, in sustaining the Carter patent as valid and infringed under such circumstances, has rendered a decision which is untenable.

POINT III.

Because petitioner is the only competitor of respondent in the field of world wide public radio telegraph communications there is no likelihood of the Carter patent being again involved in litigation in another circuit whereby diversity of opinion of Circuit Courts of Appeals would be possible.

Petitioner operates the "Mackay" Radio System, which is a public service system, handling public radio telegraph messages between the principal cities of the United States and between the United States and foreign countries. The Mackay System is the only competitor of respondent and its communications subsidiaries in world wide radio telegraph communication. The antenna structure forming the subject matter of the Carter patent is of the "directive" type that is used exclusively for point-to-point communication, as distinguished from the undirective type used for radio broadcast (*i. e.*, a *directive* antenna concentrates the radiation in the form of a narrow beam directed at a specific receiving station, whereas *broadcast* antennas are designed to radiate *in all directions*). The only other large organization interested in world wide public communications is the American Telephone and Telegraph Company and it, by virtue of its membership in the Radio Trust and patent pool, is possessed of a license under the Carter patent.

In consequence, the decision of the Court of Appeals in the present case constitutes what will undoubtedly be the sole and final decision on the Carter patent unless this Court grants a review in this case.

POINT IV.

The facts and circumstances of this case place it in that class of cases in which this Court has granted writs of certiorari in the absence of diversity of opinion between Circuit Courts of Appeals.

It is respectfully urged that although there is here no diversity of opinion between Circuit Courts of Appeals, in view of the great public importance of the subject matter involved; in view of the untenable character of the decision of the Court below because of the doctrine of *Adamson* v. *Gilliland, supra;* and in view of the probability, for the reasons given above, that the Carter patent will never again be in litigation, the present case belongs to that class of cases in which this Court has granted writs of certiorari in the absence of diversity of opinion between Circuit Courts of Appeals.

Schribner-Schrott Co. v. *Cleveland Trust Co., Chrysler Corp.*, No. 674, October Term, 1937; certiorari granted May 31, 1938;

The Barber Asphalt case, 302 U. S. 458;

Paramount Publix Corp. v. *American Tri-Ergon Corp.*, 294 U. S. 464;

Altoona Publix Theatres Inc. v. *American Tri-Ergon Corp.*, 294 U. S. 477;

Carbice Corp. v. *American Patents Development Corp.*, 283 U. S. 27;

DeForest Radio Co. v. *General Electric Co.*, 283 U. S. 664.

POINT V.

The Carter patent is invalid because of improper amendment thereof, and because it is completely anticipated by and discloses no patentable invention over the prior published art.

While it is impractical to here indulge in an extended discussion of the subject matter and merits of the Carter patent, it is believed that a cursory examination of the record will show the two salient grounds of invalidly mentioned in this heading.

The patent purports to cover an antenna structure, the wires of which are arranged in the form of a V. The patent no less than eleven times (see Vol. I, R. 313, 318) emphasizes as its main feature the procurement of predominant radiation *in the plane of the wires and along the direction of the axis of the conductor system* (see, for example, claim 19). This was categorically admitted by respondent's expert (Vol. I, R. 269).* In order to accomplish this result it

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* In this connection it should be pointed out that the Carter patent teaches that all radiation from the antenna, at all times, is *"in the plane of the wires"*, and along the axis or bisector of the angle formed by the legs of the V; and the specification points out (Vol. II, p. 688, line 27 *et seq.*) that if it is desired to radiate at *an angle* to the earth's surface it is necessary to tilt the wires to that desired angle.

As distinguished from this, petitioner's antennas are so designed that they deliberately and intentionally do *not* radiate in the plane of the wires. To the contrary, the radiation is intentionally effected at a substantial *angle* to the plane of the wires. As to this the Trial Judge found (Vol. II, 1375, fol. 4123):

> "Defendant does not radiate in the plane of the wires, whereas the third Carter patent in suit is expressly limited as to some claims, and impliedly as to all thereof, to radiation in the plane of the wires, and, in fact, on the line bisecting the angle between the legs of the V."

Again the Court said (p. 1378, fol. 4132):

> "As I have hereinbefore stated, defendant's antennas radiate at an angle to their planes and to their bisectors, *and this is contrary to Carter's teachings.* The third Carter patent in suit deals *only* with horizontal radiation from an antenna in the plane of the wires and the bisector of the angle." (Italics ours.)

is necessary that the wires forming the legs of the V be arranged at a specifically predetermined angle. In other words, the angle of the direction of radiation relative to the radiating wire must be determined. The mathematical formula for this determination—known as the Abraham formula—has been known in the art since 1898 (Vol. II, R. 960, 970). The Carter patent purports to cover the application of the old Abraham formula to V-antenna wires (see, for example, claims 9 *et seq.*, Vol. II, R. 689, wherein the Abraham formula is claimed). However, the Abraham formula is correctly applied *only* if the antenna wires are *an odd or even multiple of half wave lengths long.* It *cannot* be correctly applied to antenna wires which are not *exactly* an odd or even multiple of half wave lengths long.

The Carter application, as filed, and as it stood in the Patent Office until after petitioner's answer had been filed in this suit, dealt only with antenna wires a plurality of half wave lengths long to which the Abraham formula was correctly applicable. For example, claim 5 of the application (see Vol. II, R. 1255) defined the length of the conductors as "substantially a plurality of half wave lengths long".

All of petitioner's antennas (with one exception) varied from an integral multiple of half wave lengths by approximately one-quarter wave length, *i. e.*, varied about as much as was physically possible. This, of course, was made known to respondent shortly after petitioner's answer was filed in May, 1934. In consequence, in August, 1934, respondent amended the Carter specification by adding thereto the paragraph now appearing on page 4, lines 35-42, inclusive, of the patent, as follows (Vol. II, R. 688):

> "By the term 'plurality of wave lengths', or 'plurality of half wave lengths', or 'several half wave lengths', it is not intended that the wires so

> described shall necessarily be an exact or approximate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified."

In consequence, claims, such as claim 5, which theretofore had claimed "substantially a plurality of half wave lengths long" were amended at that time (August 4th—see Vol. II, R. 1335) to read:

> "of a length *including* substantially a plurality of half wave lengths".

This amendment, which so radically changed the disclosure of the Carter application, and the invention claimed thereby, was never supported by the oath of the inventor, and was quite obviously made for the purpose of attempting to remodel the alleged invention of Carter so as to include within its claims petitioner's antenna structures—something that was never contemplated by Carter nor included in his inventor's oath as prescribed by the statutes. This could not be legally done.

> *Chicago & N. W. R. Co.* v. *Sayles*, 97 U. S. 554;
> *DeForest* v. *General Electric Co.*, 283 U. S. 664;
> *Lopulco Systems Inc. et al.* v. *Bonnet Co.*, 24 Fed. (2) 510;
> *Irving Air Chute Co.* v. *Switlik Parachute Equipment Co.*, 82 Fed. (2) 644.

On this point the District Judge held (Vol. II, R. 1377, fol. 4129):

> "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well. Carter throughout the specifi-

> cation dealt with conductors measured in half wavelengths or full wavelengths and did not mention conductors a multiple of a quarter wavelength long, or conductors of greater or less than half wavelengths. The two Abraham formulae are applicable only to wires an exact number of half wavelengths long."

The Court further said (fol. 4131):

> "• • • by those amendments the plaintiff attempted to mold the third Carter patent both as to disclosure and claims, to cover defendant's antenna systems. This could not lawfully be done."

Moreover, there was not the slightest vestige of novelty in the Carter patent. The asserted invention of the prior Lindenblad patent (Vol. II, R. 672), which admittedly preceded Carter, shows that a V-antenna was old in the art.* The District Court's holding of non-infringement of this Lindenblad patent was affirmed by the Court of Appeals.

In addition, the use of the Abraham formula to determine the angle of radiation relative to the radiator (the stated purpose for the formula in the original Abraham articles) is shown in the Lindenblad Patent No. 1,884,006, Vol. II, R. 658, which, likewise, it is conceded, preceded Carter. This Lindenblad patent was one of the patents in suit, and was held not infringed by the Trial Judge, in which holding respondent acquiesced.

It is believed that the foregoing is sufficient to demonstrate quite conclusively the utter want of validity for the

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* See, also, French Bethenod Patent No. 596,737 (Vol. II, R. 1027) which (R. 1029) points out that the antenna wires may be

> "inclined not only with respect to the ground, but also with respect to one another so as to obtain directional effects either in the horizontal plane or in the vertical plane or in both planes."

See, also, Levy patent (R. 1076) where the antenna wires are *shown* arranged in a V with respect to each other.

Carter patent, either as a matter of law or as a matter of subject matter. In view of the other factors of the case, previously reviewed, this emphasizes the necessity for review by this Court to prevent grave injustice being done in a matter of great legal, economic, and public importance.

Conclusion.

Wherefore, petitioner earnestly prays that the petition for writ of certiorari be granted, the cause reviewed, and the decree of the Court of Appeals for the Second Circuit reversed.

Respectfully submitted,

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IN THE

Supreme Court of the United States

October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

REPLY BRIEF FOR PETITIONER IN SUPPORT OF PETITION FOR WRIT OF CERTIORARI.

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HUGH M. MORRIS,
PAUL KOLISCH,
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Most of respondent's arguments are completely refuted by the record, as pointed out by the petition for writ of certiorari. In consequence, this reply is confined to three topics, as to which respondent's brief is so flagrantly erroneous that comment thereon is necessary.

1. Respondent advances the argument to the effect that nothing in the world is further from its mind than to establish or enforce, by means of the patent here involved, a monopoly in the important industry of public service radio telegraph. In support of its argument to this effect respondent asserts (going outside of the record to do so) that, subsequent to the opinion of the Court of Appeals, it has offered petitioner a license under the patent in suit.

Although this is not of record, it is true; but we ask the Court's consideration of the terms of the license—viz.: *4½% of the* GROSS *revenue* of the licensee derived from its public service radio telegraph communication business (see the last long paragraph of Appendix B, p. 18 of respondent's brief). In other words, respondent brazenly *asserts* that it, as a condition precedent to the competition, seeks to levy a tribute of 4½% of the *gross* revenues of its only competitor in world-wide radio telegraph communication—and this on a patent which it elsewhere asserts in its brief is of extremely limited scope, and which patent the District Court found to be utterly worthless as to subject matter and invalid at law.

According to the published annual statement of petitioner for 1937, filed with the Federal Communications Commission, a levy of 4½% on petitioner's gross income ($1,026,318) would represent approximately 200% of its net income ($23,662)* for that year. Similarly, according to the published statement of respondent, Radio Corporation of America, for the same year, a levy of 4½% on respondent's gross revenue ($111,852,876) would represent over 55% of its net income ($9,024,858). It is obvious that no public service corporation could exist under such a burden. It is apparent therefore, on analysis, that respondent's plea that instead of trying to eliminate competition it is seeking to encourage it, is nothing more than a sham.

2. Respondent likewise goes outside of the record to refer to a license which it asserts it has granted, on the onerous terms above stated, to Globe Wireless, Ltd. The record discloses nothing about that concern. For all the record discloses it may be a subsidiary of respondent. If, in

* Exclusive of intercompany interest on borrowed capital.

fact, it has acquired a licence on the terms of 4½% of its *gross* revenues, it may well be that it is dominated or controlled by respondent. We know that Globe Wireless, Ltd, is *not* engaged in world-wide radio service, and in that field is *not* a competitor of petitioner. Because of that knowledge we assert that it is not a competitor of respondent in that field.

3. Respondent asserts that one of the members in the "Radio Trust", viz.: American Telephone and Telegraph Company, assisted petitioner at the trial of this cause (*e. g.*, see respondent's brief, p. 2). This is entirely untrue. The American Telephone and Telegraph Company, one of the parties to the radio patent pool, had relevant facts and documents in its possession. Petitioner demanded that these facts be made available for consideration by the Court in this case. That demand was complied with *after* the said facts had been made known to respondent by the American Telephone and Telegraph Company *prior* to the trial. Counsel for respondent had in his possession at the trial (and presumably for many days prior thereto) photostatic copies of all of the documentary exhibits which the employees of the American Telephone and Telegraph Company were required to produce.

Conclusion.

We submit as quite apparent that where a litigant is compelled to go to the extremes to which respondent is driven in its present brief in the foregoing instances to which we confine our comments, there must, indeed, be merit in the opposing cause sufficient to warrant, for the public interest, a review by this Court of the issues in controversy.

Therefore, the grant of the petition is most earnestly urged.

Respectfully submitted,

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BRIEF FOR RESPONDENT IN OPPOSITION TO PETITION FOR WRIT OF CERTIORARI

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Statement.

Petitioner's "Summary and Short Statement of the Matter Involved" (pp. 2 to 5 of the Petition) opens with three paragraphs which, due to misleading and incorrect statements for which there is no basis in the record and which are now for the first time injected into the suit, give a false picture of the background of the litigation. Other paragraphs of petitioner's Summary likewise contain matters outside of the record and statements that are misleading and incorrect.

To correct the impression sought to be given by petitioner as to the "atmosphere" of the suit, respondent re-

*The opinion of the District Court herein is reported in 16 Fed. Supp. 610, and that of the Circuit Court of Appeals is reported in 96 F. (2d) 587.

states the subject matter of the first three paragraphs of petitioner's Summary as follows:

1. This is a patent infringement suit brought by respondent, Radio Corporation of America, on patents owned by that company. The invention set forth in the patent now before this Court was made by one of respondent's engineers after extensive research and experimentation had been carried on by respondent and its subsidiaries over a period of many years. American Telephone and Telegraph Company assisted petitioner at the trial herein in its attempt to invalidate certain of the patents including the one which is now before this Court. Instead of petitioner's facing a group it calls the "Radio Trust", the facts show that it was assisted by one of the corporations which it asserts (foot-note, p. 2) is a member of that group.

2. Petitioner is a public service company engaged in the radio telegraph transmission of public messages between the principal cities of the United States and foreign countries. Petitioner is not the only competitor of respondent's subsidiary, RCA Communications, Inc., in this field,—Globe Wireless Ltd. being another competitor. Respondent has licensed Globe Wireless Ltd. under the patents in suit and other patents useful in this field,* and has offered a license on the same terms to petitioner.

3. The present suit is an effort of respondent to require petitioner to pay for its appropriation and use, in competition with respondent's licensees (including its communications subsidiary), of inventions developed by respondent's engineers which promote reliable and economical radio communication.

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*This is a matter of public record of which, we assume, the Court may take judicial notice. See, for example, extracts from proceedings before the Federal Communications Commission, quoted in Appendix A, *infra*, p. 17.

Summary of Respondent's Position and Argument.

For the sake of brevity and clearness, respondent, rather than restating, from its point of view, the subject matter of the remaining paragraphs of petitioner's Summary, indicates what it believes to be proper additions and corrections in connection with the following reply argument, arranged to correspond in number and subject matter to petitioner's "Reasons Relied Upon for the Grant of a Writ of Certiorari." A summary of respondent's position and argument follows:

I. (a) Under the facts of the present suit, the belated suggestion that respondent is a part of a "Radio Trust" and that the patent in suit is involved in a "patent pool" can furnish no basis for a review of this suit.

(b) Enforcement of the patent in suit would not give respondent a monopoly in public service radio telegraph communication because—

(1) petitioner was in that business before the patented invention came into use;

(2) numerous non-infringing types of directive antenna are shown by the record to have been used;

(3) petitioner's counsel has stated, since the decision of the Court of Appeals herein, that the infringing antennas have already been changed to a non-infringing form;

(4) petitioner is not the only competitor of respondent in this field; and

(5) petitioner has been formally offered a license under all of respondent's patents relating to radio communication on terms that have been accepted by another competitor.

II. The Court of Appeals did not reverse essential findings of fact made by the Trial Court on conflicting evidence, but merely reversed *conclusions* based on interpretation of the patent in suit and undisputed facts as to the structure and operation of petitioner's antennas and upon documentary evidence. This appears from the opinion of the Court of Appeals.

III. There is no reason to assume or assert that there is no likelihood of the Carter patent's again being involved in litigation in another Circuit.

IV. This suit does not involve any matters of great public interest or doubtful questions of law such as those considered in the cases cited by the petitioner. This is a simple patent suit involving a specific form of antenna which defendant may use, by paying a royalty, or without which, as it now asserts, it can carry on its business. No question of any kind whatever other than validity and infringement of the patent in suit is raised by the pleadings or proofs herein.

V. (a) Petitioner's statement that the patent is invalid because of improper amendment during prosecution of the application involves merely a consideration of the file history of the application. No conflicting testimony is involved. Respondent does not dispute the principle of law that new matter cannot be inserted by amendment. This issue was decided against petitioner by the Court of Appeals. An examination of the file history, which is in the record, will show that the decision of the Court of Appeals is correct.

(b) Petitioner's argument that its antennas were built before the patent issued, and that the patent in suit was

molded to cover its antennas, not only ignores the fact that the application for the patent, as filed, described the antennas subsequently built by petitioner, but also the fact that a complete description of the antenna as already built by respondent and as described in the patent had been published by the patentee the year before petitioner erected the infringing antennas.

(c) Petitioner's argument that the patent "is completely anticipated by and discloses no patentable invention over the prior published art" is sufficiently disposed of by the discussion of the prior art contained in the opinion of the Court of Appeals. The Trial Court did not hold the Carter patent invalid over the prior art.

ARGUMENT.

Point I. Answer to Petitioner's first Reason for asking for Certiorari.

(a) Petitioner asserts that the patent in suit is "in the patent pool which forms the so-called 'Radio Trust' ".

This fact, if it were a fact, could only be of interest if the decision below would give to respondent, as a supposed member of the so-called "Radio Trust", a practical monopoly in the public service radio communication business. As we will show, later on under this Point, the decision cannot have that effect. But aside from that, the following facts should be noted:

Petitioner was assisted at the trial by American Telephone and Telegraph Company, which petitioner asserts to be a member of what it calls the "Radio Trust". Petitioner called six witnesses* who were employees of a subsidiary company of American Telephone and Telegraph

*Rec., Vol. I, pp. 493, 552, 553, 557, 559, 577.

Company in an effort to establish prior invention of the subject matter of the Carter patent which is now before this Court. Furthermore there is not one word of pleading, testimony, or other evidence intended or tending to show that the present suit is directed, as petitioner alleges, to an effort on the part of respondent to eliminate competition in its public service operations. The suit furnishes no vehicle for consideration of the collateral issues that petitioner seeks to inject for the first time in this Court. Therefore the *innuendo* involved in the reference to the so-called "Radio Trust" furnishes no basis for review of this suit.

(b) Petitioner asserts that enforcement of the patent in suit would vest in respondent "a complete monopoly in public service radio telegraph communication" and that the decision of the Court of Appeals therefore materially affects public interest. This argument is based on false premises.

(1) Petitioner was in the public service radio communication business before it used the specific V-form directive antenna structure which alone is involved in this suit. Furthermore, the record shows* that, after the commencement of the present suit, there were installed, at petitioner's Sayville, Long Island, station, non-infringing types of antennas for communication with Europe, South America, San Francisco, etc.

(2) There are numerous other types of directive antennas described in this record, some of which are shown in foreign patents or patents that have expired and which are therefore open to petitioner to use for carrying on its business. Types of directive antennas that have been successfully used commercially and

*Vol. I, pp. 73-74; Vol. II, p. 810.

which do not embody the Carter invention are described in the record at pages 55-65 and 71-73 of Vol. I. All that petitioner is confronted with is the necessity of paying royalty if it desires to use the specific antenna structures developed by respondent and covered by the patent in suit.

(3) Petitioner's counsel, since the decision of the Second Circuit Court of Appeals in this case, has asserted *that petitioner has already changed its antennas over to a non-infringing and better form.*

(4) Petitioner is not the only competitor of respondent's communication subsidiary. Globe Wireless Ltd. is competing with respondent under license under respondent's patents, and there is a Mackay Radio and Telegraph Co. of California that is engaged in competition both with respondent's subsidiary and with Globe Wireless.

(5) Respondent has for years held the door open to petitioner to take a license under its patents. *Shortly after the decision of the Second Circuit Court of Appeals herein, respondent formally offered to license petitioner under the Carter patent and all other of its patents in the communication field upon the same terms that respondent has licensed its own communication subsidiary and Globe Wireless Ltd.**

Point II. Answer to Petitioner's second Reason for asking for Certiorari.

Petitioner asserts that the Court of Appeals in finding the Carter patent valid and infringed reversed "every essential finding of fact made by the District Judge on conflicting

*This offer was made by a written communication between the parties hereto, quoted in Appendix B, *infra*, pp. 17-18.

evidence," and that this action was contrary to the rule of *Adamson* v. *Gilliland*, 242 U. S. 350.* Petitioner refers to two findings which it says should have been treated as unassailable, namely (1) that petitioner's antennas differed radically from those disclosed in the Carter patent, and (2) that the application for the Carter patent was improperly broadened in scope during the prosecution thereof in the Patent Office.

Petitioner's position is unsound because the Court of Appeals merely reversed *conclusions* drawn from *undisputed* facts.

(1) *There was no conflict in the evidence relating to the facts upon which the Trial Court's conclusions as to infringement of the Carter patent were based.* The conflict was as to the *disclosure* and *interpretation* of the patent in suit. The Trial Court, in its opinion, at 16 Fed. Supp. 611 (Rec., Vol. II, p. 1347), said:

> "*There is no dispute* as to the construction or arrangement of the defendant's antenna systems, and they are *fully described in the agreed descriptions*, diagrams, and tabulations of dimensional data comprising plaintiff's Exhibits 7 to 13, inclusive." [Rec. Vol. I, pp. 46-7; Vol. II, pp. 693-718.]**

Likewise, the expert witnesses for both parties agreed as to the operation of petitioner's antennas.†

With respect to the Carter patent that is before this

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*The issue of fact which was involved in the *Adamson case* was one that was required to be proved "beyond a reasonable doubt". The case of *Davis* v. *Schwartz*, 155 U. S. 631 (which this Court cited in the *Adamson case* on this point), specified the situations in which findings of fact must be treated as unassailable; the trial in open court of a suit in equity was not one of the specified situations. Where, as in the present suit, the findings of the Trial Court do not depend upon conflicting testimony or upon the credibility of witnesses, they do not have the weight ordinarily attaching to findings of fact. *Morimura, Arai & Co.* v. *Taback*, 279 U. S. 24, 33.

**Emphasis throughout this brief is ours.

†Rec., Vol. I, pp. 399-401, XQ. 1167.

Court, the Trial Court did not even discuss the prior art antenna patents. Its only "essential finding" was non-infringement, based on its conclusion that the operation of the petitioner's antennas was not that described in the patent. Since the *structure* and *functioning* of petitioner's antennas were undisputed, the finding was obviously based on an *interpretation* of the patent, a matter of law for the Court. Consequently, in reversing on this point, there was no overruling of any finding of fact (essential or otherwise) based on testimony. That appears quite clearly from a comparison of the two opinions below.

For example, the opinion of the Court of Appeals, at 96 F. (2d) 589, 590 (Rec., Vol. II, pp. 1404, 1405), covers the matter of infringement as follows:

> "Appellee [petitioner] constructs its V-antennas • • • utilizing in most instances substantially the exact angle specified by Carter, and places them upon poles 80 feet high and secured antennas that were effective in the identical directions that Carter described. *Structurally the antennas are Carter's and secure the same results as he describes,* that is, concentration of radiation on the distant receiving antenna, simplicity, and efficiency. They are used to obtain the results Carter sought.
>
> • • •
>
> "The main consideration is that Carter described a practical directive antenna which is of great commercial utility when used just as he said it was to be used. He was concerned with antennas which would concentrate the radiation in certain compass directions. *These antenna structures are used by both appellant and appellee.*"

Every *fact* stated in the foregoing quotation was clearly established by the record.* Petitioner sought to limit the

*Petitioner does not assert that the decision of the Court of Appeals is not sustained by the record, but merely (pp. 5, 13) that that court did not "cite any evidence" to support its conclusions.

patent disclosure to predominant radiation, at all distances from the antenna, in an exact plane and on a line in that plane. The Trial Court accepted that argument. The Appellate Court rejected such a narrow *interpretation* in the words above quoted.

(2) As the matter of the amendment of the application for the Carter patent is specifically mentioned in petitioner's fifth reason relied upon for the grant of the writ, that matter will be discussed below under Point V, section (a).

Point III. Answer to Petitioner's third Reason for asking for Certiorari.

Petitioner says there is no likelihood of further litigation on the Carter patent. In making this statement, petitioner overlooks a number of facts.

Thus, there is a Mackay Radio and Telegraph Co. incorporated in the State of California which we are informed is not a subsidiary of petitioner. This California corporation, so far as known to respondent, is not engaged in business in the Second Circuit but is engaged in business in the Ninth Circuit and possibly elsewhere. The California corporation has utilized, in its public radio telegraph communication business, antennas embodying the invention of the Carter patent in suit. If that use is continued, the Carter patent will undoubtedly be involved in further litigation in another Circuit than the Second Circuit.

Furthermore, although the Carter antenna is of the directive type and is, therefore, particularly adapted to point-to-point communication, yet "world-wide public radio telegraph communication" is not the only type of point-to-point communication. In fact, the Carter antenna is now in use for other purposes.

There is thus no reason to assume or assert that there is no likelihood of its again being involved in litigation in another Circuit.

Point IV. Answer to Petitioner's fourth Reason for asking for Certiorari.

We respectfully submit that there are no facts or circumstances in this case which call for the exercise of this Court's discretion to grant the writ of certiorari in the absence of a diversity of opinion between Circuit Courts of Appeals. There is no novel, doubtful, or unsettled proposition of law involved in the case and for this reason the situation which existed in *The Barber Asphalt case,* 302 U. S. 458, and in the *Carbice Corporation case,* 283 U. S. 27, is not here present. Neither is the patent of such character as to dominate an entire industry, as was the case with respect to the Langmuir so-called "high vacuum patent" which was involved in the *DeForest Radio Co. case,* 283 U. S. 664, and which, if sustained, would have given its owner a practical monopoly with respect to a device essential to all phases of the radio art,—the vacuum tube. Neither have there been subsequent suits instituted on the Carter patent in an effort to dominate an industry as was the case in the *Paramount-Publix Corporation* and *Altoona Publix Theatres, Inc., cases,* 294 U. S. 464 and 477. Neither is the situation in the present case like that which existed in the *Schriber-Schroth Co.* v. *Cleveland Trust Co.* and associated cases, 303 U. S. (Advance Sheet No. 2, page v), where three suits had been instituted in the Sixth Circuit and where the decision of the Sixth Circuit Court of Appeals controlled "virtually the entire industry throughout the United States, at least ninety-five per cent. of it" (quoting from the Second Petition for Rehearing therein).

The present case, involving no diversity of opinion between Circuit Courts of Appeals, and no novel, doubtful, or unsettled proposition of law, no decision that is inconsistent with decisions of this Court, and no question of great public interest, is clearly not one calling for the exercise of this Court's discretion to review the decision of the court below.

Point V. Answer to Petitioner's fifth Reason for asking for Certiorari.

(a) Petitioner asserts that the patent in suit is invalid because of improper amendment of the application after knowledge was obtained of petitioner's antenna structures. The amendments which petitioner criticizes were filed July 13, 1934, and August 4, 1934, which (contrary to petitioner's assertion) was *prior* to respondent's receiving the particulars as to the structure and operation of petitioner's antennas, which information was received on August 14, 1934.

This question of departure from the original subject-matter revolves around whether or not the original application disclosed and claimed antenna wires that were not, in length, multiples of half a wave length. Petitioner argued that claims and description addressed to such matter had been inserted by amendment. It referred the Courts below to amendments that rephrased and emphasized such subject-matter, but *ignored the original application upon which the amendments were based.*

The file history of the patent in suit is reproduced in the record (Vol. II, pp. 1244-1343). It shows that *Carter's application as filed described and claimed the structure that petitioner uses.* See, for example, claims 19 and 20

of the original application at Vol. II, p. 1259. *These claims in their original form read directly on petitioner's antennas in both words and substance.* They were never canceled, and with certain amendments of detail, constitute the claims now in suit. And see also the fourth paragraph,* Vol. II, page 1244, and the last paragraph** on page 1250, Vol. II of the record, in the application *as filed.* These parts of the original specification clearly cover wires of "any finite length" and specifically refer to wires having "lengths *between* odd and even number of half wave lengths".

Petitioner made this same argument on the file history to the Trial Court, which followed the argument literally, apparently without reading the application as filed. Petitioner repeated this argument to the Second Circuit Court of Appeals, *which specifically reversed the Trial Court on this point,* saying, in its opinion, at 96 F. (2d) 590 (Rec., Vol. II, p. 1405):

> "Carter's *application* stated that the invention was applicable to wires of any finite length. His *original application* included the empirical formula and the curve of that formula is shown and described."

---

*"Still a further object of the present invention is to disclose the proper angle for conductors or radiators either an even number of half wave lengths long or an odd number of half wave lengths long, and, in general to disclose the angle for best directional propagation for wires of any finite length."

**"Moreover, it should be clearly understood that the wires of each unit can be of any length whatsoever provided they are placed at the correct angle for their length. For best tuning, the total overall length of both of the wires and the 'U' loop terminating them should be effectively an integral number of half wave lengths, but, the portion forming the radiation element can be of any length. The law, giving the correct angle for lengths between odd and even number of half wave lengths, is not given due to its complexity, but, the empirical formula and the curve of figure 12 will be found accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths."

In effect, what petitioner now asks this Court to do on this point is to study the voluminous file history and determine whether the Second Circuit Court of Appeals was right in saying that the original application supports the claims in suit, or the Trial Court was right in saying that it does not. *There is no other evidence pertinent to this issue. There is no conflict of testimony upon it. Decision of this issue is purely a matter of construing a written record.* No law point is involved because respondent has not questioned the established law as to insertion of new matter by amendment.

(b) Paragraph 9, page 5, and later argument in the petition might lead the Court to believe that there is some equity in petitioner arising from the fact that its antennas were erected and their structure disclosed to respondent prior to *issuance* of the patent in suit. Petitioner omits telling the Court that *before petitioner erected any of the V-antennas here involved, respondent's engineers had produced the Carter V-antenna covered by the patent in suit, had erected and used it commercially, and had given a complete technical, structural, and operative description of this antenna in a paper delivered before the Institute of Radio Engineers on June 6, 1931,* and published in the Proceedings of the Institute for October, 1931. That paper is printed at pages 725-794 of Vol. II of the record. It contained, according to undisputed testimony,

> "sufficient information as to structure, arrangement, and adjustments to enable a radio engineer to construct and operate the antennas there described." (Rec., Vol. I, p. 67.)

It was in the year following this published description of the Carter antenna that petitioner built its infringing an-

tennas, copying the Carter V-antenna disclosure of the previously published scientific paper with great fidelity of detail and without adding any new or improved feature. In spite of the fact that petitioner's Chief Engineer testified at the trial (Rec., Vol. I, p. 285), there is no testimony in the record denying the clear inference that petitioner copied the antennas that had been erected by respondent's subsidiary and publicly described by the inventor. Under such circumstances, there can be no equity in petitioner arising from the fact that the Carter patent did not issue until after its antennas were erected.

(c) The petition also asserts in its fifth reason for asking for certiorari that the Carter patent "is completely anticipated by and discloses no invention over the prior published art".

The Trial Court did not discuss any published prior art descriptive of antennas, and did not hold the Carter patent invalid over the prior art. The Court of Appeals discussed the prior art relied on by petitioner and held the patent valid. There is therefore no conflict of opinion below as to validity. No reason for this Court to review the decision on validity appears from petitioner's argument. We think it superfluous in this brief to seek to add to the opinion of the Court of Appeals on this point.

CONCLUSION.

The subject-matter of the present suit is not, as petitioner would make it appear, petitioner's right to stay in the business of public service radio communication. It involves merely petitioner's right to infringe a patent of which the Second Circuit Court of Appeals says:

> "The *problem solved here was of long standing* and it was an *eminently successful solution.* Critical examination of prior patents and uses finds nothing invalidating the Carter invention and it *shows a substantial accomplishment.*" (96 F. (2d) 591; Rec., Vol. II, p. 1408.)

The *sole* questions in the case now are whether that patent is valid and infringed. There are no pleadings or proofs furnishing any basis for consideration of any other question.

There is no novel, doubtful, or unsettled proposition of law even asserted by the petition. Respondent does not question the principles of law that would make a patent invalid if the claims in suit were added by amendment without proper basis in the application as filed, or that findings of circumstantial fact of a Trial Judge based on conflicting testimony are generally to be followed by the Courts of Appeals. Such law is fully established and is undisputed here. This Court could add nothing to it in this case.

There is no more reason for this Court's reviewing the present suit than for its reviewing each and every suit where a patent has been held valid and infringed.

We submit that the petition is without merit and should be denied.

Respectfully submitted,

Jo. Baily Brown,
Abel E. Blackmar, Jr.,
Counsel for Respondent.

APPENDIX A

Excerpts from statement made to Federal Communications Commission June 23, 1938, concerning the license from Radio Corporation of America to Globe Wireless Ltd., dated February 11, 1938.

"Globe is licensed to make or have made for it all radio apparatus required for rendering a radio telegraph public service and therefore may obtain its apparatus requirements from any source which it may use. * * * RCA has agreed to furnish to Globe with the latter's apparatus requirements at prices and upon terms and conditions as favorable as those granted to other customers purchasing such equipment in similar quantities. * * * RCA has also agreed to furnish information to enable Globe to adopt and utilize apparatus and technical improvements similar to those utilized in commercial service by RCA, and its subsidiaries rendering telegraph public service."

APPENDIX B

[Letter-head of Radio Corporation of America]

May 4, 1938.

Mackay Radio & Telegraph Company Inc.,
67 Broad Street,
New York City.

Gentlemen:

This refers to the decision of the United States Circuit Court of Appeals for the Second Circuit handed down on May 2, 1938 holding our Carter patent No. 1,974,387 dated September 18, 1934 valid and infringed by the Mackay Radio & Telegraph Company, Inc.

[APPENDIX B, *continued*]

As you know, Radio Corporation of America has heretofore expressed its willingness to grant a license under its patents to Mackay Radio & Telegraph Company, Inc. In 1929 a license was offered to you, and in a recent public hearing before the Federal Communications Commission our counsel renewed the expression of willingness to license you. This was in accordance with the policy of RCA to license its competitors including those in the fields of public service radio telegraph communication. Among others, a license has been granted to Globe Wireless, Ltd. in this field.

Radio Corporation of America hereby repeats its offer to grant to Mackay Radio & Telegraph Company, Inc. a license under its patents including the above-mentioned Carter patent and all others in respect of which it has the right to grant licenses to others. The royalty under such a license would be four and one-half per cent (4½%) of the Mackay Company's gross revenues derived from its public service radio telegraph communications business. This is the same royalty as that payable by Globe Wireless, Ltd. and by our subsidiary, RCA Communications, Inc., under their license agreements with us.

If you are interested in acquiring such a license we shall be pleased to enter into the negotiation thereof with you.

Yours very truly,

O. S. SCHAIRER
[*Vice President*]

OSS:MH.

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Supreme Court, U. S.
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CHARLES ELMORE CROPLEY
CLERK

IN THE

Supreme Court of the United States

October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

BRIEF FOR PETITIONER.

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IN THE

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October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

BRIEF FOR PETITIONER.

This is a patent infringement suit, here on writ of certiorari to the Circuit Court of Appeals for the Second Circuit.

Opinions of the Courts Below.

The opinion of the District Court for the Eastern District of New York is reported in 16 Fed. Supp. 610 (Vol. II, p. 1133).

The opinion of the Court of Appeals is found in 96 Fed. (2d) 587 (Vol. II, p. 1167).

Jurisdiction.

The date of the judgment to be reviewed is May 2, 1938.

The writ of certiorari was granted by this Court on October 10, 1938. The jurisdiction of this Court is invoked

under Judicial Code 240-A, as amended by the Act of February 13, 1935.

The cases believed to sustain the jurisdiction are:

The Barber Asphalt case, 302 U. S. 458;
Paramount Publix Corp. v. *American Tri-Ergon Corp.*, 294 U. S. 464;
Altoona Publix Theatres Inc. v. *American Tri-Ergon Corp.*, 294 U. S. 477;
Carbice Corp. v. *American Patents Development Corp.*, 283 U. S. 27;
DeForest Radio Co. v. *General Electric Co.*, 283 U. S. 664.

Assignment of Errors.

The errors which petitioner urge are:

(1) The Circuit Court of Appeals erred in sustaining Carter Patent No. 1,974,387 as valid and infringed.

(2) The Court of Appeals erred in overruling every essential finding of fact of the District Court with respect to the issues relevant to the Carter patent, without authority in or reference to the evidence.

(3) The Court of Appeals erred in failing to affirm the District Court on the facts found by that Court and established by the record, that the Carter Patent No. 1,974,387 is invalid because of unlawful amendment to its statement, description and claim of invention.

(4) The Court of Appeals erred in failing to affirm the District Court's finding of fact that petitioner's antenna structures, charged to infringe, differ "radically" "in structure, principle of operation and instrumen-

talities" from that of the patent, and operate on principles not only different from those of the patent but "contradictory thereto as well".

(5) The Court of Appeals erred in failing to hold Carter Patent No. 1,974,387 invalid as completely anticipated by and wanting in invention over the prior art.

Statement of the Case.

1. Petitioner is a public service corporation engaged, with its associated companies, in the radio transmission of public telegraph messages between the principal cities of the United States and with foreign countries. In this respect petitioner, and its associated companies, constitute the only competition to the world-wide public radio telegraph service operations of respondent and its subsidiary, RCA Communications.

2. Respondent, Radio Corporation of America, is a member of the radio patent pool.[1]

3. Under the patent pool the various "fields" of the electrical industry were allocated to the respective members thereof. Thus, to American Telephone and Telegraph Company was allocated the *telephone* communications field, and the *talking motion picture* field was jointly shared by respondent and American Telephone and Telegraph Company.[2] To respondent alone was allocated the field of world-wide *radio telegraph communication.*

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[1] See—*Lord* v. *Radio Corporation of America,* 24 Fed. (2) 565; *Radio Corporation of America* v. *Lord,* 28 Fed. (2) 257; *Lord* v. *Radio Corporation of America,* 35 Fed. (2) 962; *Radio Corporation of America* v. *de Forest,* 47 Fed. (2) 606.

[2] *Stanley Company of America* v. *American Telephone & Telegraph Co., General Talking Pictures Corp.* v. *American Telephone & Telegraph Co., Duovac Radio Corp.* v. *American Telephone & Telegraph Co.,* 4 Fed. Supp. 80; *Same* v. *Same,* 18 Fed. Supp. 650.

4. The present suit is an effort on the part of respondent to eliminate competition in public service world-wide radio telegraph communications.

5. Respondent initially filed suit charging petitioner with infringement of four patents (all included in the radio patent pool, see footnote 1, p. 3) having to do with various features of radio antennas and their operation. At the time the bill was filed, respondent had pending in the Patent Office, in the name of one Carter, an application for a *fifth* patent for an antenna structure. Subsequent to petitioner's answer in the suit, and after receiving particulars as to the structure and operation of petitioner's antennas, respondent completely altered the statement and claim of invention of the pending Carter application in the attempt to include petitioner's antenna structures.[3]

6. Thereafter, the Carter patent issued (referred to in the litigation as the "Third Carter patent") and a supplemental bill of complaint was filed charging infringement thereof. The suits were consolidated, and the parties proceeded to trial on all five patents before Judge CAMPBELL in the Eastern District of New York.

7. After a trial which lasted nearly a month, Judge CAMPBELL filed an opinion finding as a fact, on the conflicting evidence before him, that petitioner's antennas differed

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[3] The District Court found (Vol. II, p. 1154, fol. 1377):

> "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well";

and (p. 1155, fol. 1378):

> "* * * by those amendments the plaintiff attempted to mold the third Carter patent both as to disclosure and claims, to cover defendant's antenna systems.
>
> This could not lawfully be done."

"radically" from all of the patents "in structure, principle of operation and instrumentalities", and operated on principles not only *different* from those of the patents, but "contradictory thereto as well."[4] He also characterized the broadening amendment as unlawful, as above noted (Footnote 3, *ante*, p. 4).

8. The opinion of the District Judge showed such painstaking and thorough analysis of the evidence, and so clearly stated and decided the issues presented, after seeing and hearing the large number of witnesses of both sides testify on the facts and scientific principles involved, that counsel for petitioner and respondent stipulated that the opinion of the Court be accepted as the findings of fact and conclusions of law in the case in compliance with the provisions of Equity Rule 70-½ (Vol. II, p. 1158). In consequence, a

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[4] The District Court found (Vol. II, p. 1145, fol. 1363):

> "The defendant's antennas which are charged with infringement differ *radically* from the inventions claimed in the three antenna patents in suit". (Italics ours.)

Again, the Court found (p. 1146, fol. 1364):

> "In substance all of the antenna patents in suit present merely a theoretical application of antenna wires in free space, whereas all of the defendant's are *intentionally* designed to cooperate with ground effect, *which effect not only is not contemplated by any of the patents in suit, but is contradictory to the description and claims thereof.*" (Italics ours.)

Again, the Court found (p. 1151, fol. 1372):

> *"Due to the departure from the Carter patent in the respects enumerated and by reason thereof* in all of defendant's antennas, here charged to infringe, defendant obtains material advantages and increased efficiency in that material increase in radiated power is obtained." (Italics ours.)

and, finally, the Court found (p. 1157, fol. 1380):

> "* * * *the fact is, however, that defendant's systems are radically different from the patents in suit, in structure, principle of operation and instrumentalities,* and were designed and constructed to secure and did secure greater radiation, *by reason of such difference* than could be obtained by the patents in suit." (Italics ours.)

final decree was entered dismissing the bills of complaint, as to *all* patents, for want of equity (Vol. II, p. 1158).

9. Respondent acquiesced in the decree dismissing the complaint as to three of the patents, but appealed from that decree as to two, namely, Lindenblad Patent No. 1,927,522 and the Third Carter patent here involved.

10. The appeal was argued April 8, 1938. On May 2, 1938 the Court of Appeals announced its decision (per Judge MANTON) holding the Carter patent valid and infringed. Thereby it, in effect, reversed every essential finding of fact made by the Trial Judge, although the Court of Appeals did not point out any error in such findings, or cite evidence in support of its contrary finding. It affirmed the District Court's dismissal of the Complaint as to the Lindenblad patent.

11. The case here before the Court, therefore, is confined to the Carter patent.

Summary and Order of Argument.

Petitioner contends that the Carter patent is neither valid nor infringed, both as a matter of fact and of law.

A. As to want of infringement, petitioner asserts:

(1) That the patent is not a pioneer patent; and that the record does not show that it has ever been employed by anyone. This was found as a fact by the Trial Judge.[5]

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[5] The Trial Judge found (Vol. II, p. 1156, fol. 1380):

"None of the patents in suit are pioneer patents, as contended by plaintiff, and the record does not show that they had been employed by anyone; *even the plaintiff's own commercial structures do not follow the teachings or employ the instrumentalities shown, described or claimed in any of the patents in suit,* as I have interpreted the same." (Italics ours.)

(2) That petitioner's antennas, as was likewise found by the Trial Judge, differ "radically" from the Carter patent "in structure, principle of operation and instrumentalities", and operate on principles not only "not contemplated" by the Carter patent, but "contradictory to the description and claims thereof" as well.[6]

(3) That the Court of Appeals committed error in reversing every essential finding of fact made by the Trial Judge under such circumstances, especially where no error, manifest or otherwise, was pointed out; and where it is not even suggested (and could not be) that petitioner's evidence did not fully support the fact findings.

B. As to invalidity, petitioner asserts:

(1) That the Carter application, while pending in the Patent Office, and after respondent had obtained knowledge of petitioner's antenna structures, was altered both as to statement and claim of its alleged invention, in the endeavor to include petitioner's antennas within its scope, in a manner, as found by the Trial Judge "not only contrary to their original terminology but to their spirit as well."[7] This, as a matter of law, invalidates the patent, as the Trial Judge, in effect, held. (See footnote 3, *ante*, p. 4.)

(2) The patent is also invalid as a matter of law because the *amended* statement and claim of invention

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[6] See footnote [4], *ante*, p. 5.

[7] Vol. II, p. 1154, fol. 1377.

were never subscribed to by the inventor, nor supported by his oath as prescribed by the statutes.[8]

(3) The patent is also invalid because it is completely anticipated by and devoid of patentable novelty over the prior art.

Argument.

Before taking up specific consideration of the points of argument outlined above, it is necessary to have an understanding of the subject matter of the litigation, as well as of the patent.

Subject Matter of the Case.

We are here concerned with radio antenna structures, and, more particularly, with that type of antenna structure which is used for short-wave, directional radio telegraph communication, as distinguished from radio broadcast.

The most familiar example of radio broadcast are the news, music and entertainment broadcasts throughout the nation. The antenna employed for that type of radio communication radiates the radio waves in *all* directions so that they may be received at any and all points of the nation (and, indeed, by foreign countries).

As distinguished from this, radio *telegraph* communication, with which this case is concerned, employs a directive antenna which radiates radio waves as a *beam* directed at a particular receiving station.

Undisputedly, it has been the practice in the radio art for many years prior to the earliest date with which this

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[8] Sections 4888 and 4892 R. S. These sections of the statute will be found in the appendix hereto, *post*, p. 53.

case is concerned, to use *directive* antennas in radio telegraph communication; and for many years the simple expedient that has been employed for this purpose (and is employed in the Carter patent in suit) is to locate a *second* antenna, similar to the *radiating* antenna, and in back of it, where it serves as a "reflector", similar, in effect, to a mirror located back of a light, to concentrate the light radiations into a beam.

The patent in suit, as well as petitioner's antennas, radiate what are termed "*short*" waves, as distinguished from what the art knows as "*long*" waves. All radio waves radiated from an antenna structure have some definite length. A radio wave has been frequently pictured as similar to sea waves, and the length of a radio wave is the distance, usually measured in meters, between the crests of two succeeding waves.

The phenomenon of radio waves was first discovered by an experimenting investigator employing extremely *short* wave-lengths of the order of a few centimeters. The practical application of radio waves for communication and other purposes, however, began with much longer wave-lengths, and the trend in the art was to increase the wave-lengths in proportion to the desired distance of communication. Considerably more than a decade ago, however, the art began to swing back to the use of shorter wave-lengths, with the result that for radio telegraph communication, especially in the public utility field, it is now virtually the universal practice to radiate radio waves of short wave-lengths.

There is no sharp line of division between long wave-lengths and short wave-lengths. As a matter of practical usage, however, the art, from time to time, has arbitrarily selected a dividing line, calling all wave-lengths above a

certain length "long", and all those below that length "short". We are not here concerned, however, with any nicety of definition.

The Carter patent, not being a pioneer in any sense, and being expressly directed to a most specific detail of antenna construction, it is unnecessary to indulge in a scientific exposition of the principles underlying radio communication. For the purpose of this case a brief, non-technical explanation will be sufficient.

The Operation of a Radio System.

Radio communication requires a sending station and a receiving station. At the sending station there is provided a source of current which is fed to the transmitting antenna, and from it propagated or "radiated" as a wireless wave to the receiving station. At some point in the transmitting station the current is *altered* in some respect ("modulated" or "interrupted", as it is technically termed), by or in accordance with the signal to be transmitted. Thus, it is the "altered" wave that is radiated from the antenna. This wave impinges on the antenna at the receiving station, and affects an electric current at the receiving station. The character of effect on the receiving-station current is determined by the character of the "altered" radiated wave. This effect is "read" as the message thus transmitted and received.

The Antenna.

As above stated, the present litigation has to do solely with antenna *structure*. The effective part of an antenna structure is an ordinary copper wire from which the radio waves are radiated. These antenna wires have always been supported by "towers", "poles", or other supporting

structures, at the desired height above the ground, and in the desired parallel, vertical or angular relation to the ground, depending upon matters of design, desired functioning, etc. The height of the wire above the ground depends on the wave-length used. The art prior to the Carter patent employed antenna wires arranged vertically, horizontally, or at an angle to the earth's surface. The art likewise employed antenna structures in which more than one wire was used. Likewise, the prior art had employed antenna wires arranged angularly with respect to each other to form a "V" or an "X". Finally, the prior art used a "reflector" for rendering the antenna "directive" so as to concentrate the radiated waves into a *beam* directed towards the desired receiving station.

In short, the art prior to the Carter patent in suit disclosed a multitude of types and arrangements of antenna wires, singly or in multiples, alone or with reflector, vertically, horizontally or angularly arranged towards the earth or towards each other. This is not disputed.

Let us next turn, therefore, to the Carter patent to ascertain what it purports to add to this acknowledged prior art.

The Carter Patent.

In the first place, the patent is directed and expressly limited to but one of the old specific antenna structures, viz: one in which two radiating wires are employed, and are angularly arranged with respect to each other to form a "V". No novelty is claimed by the patent for a "V" antenna. As before stated, such an arrangement of antenna wires was concededly old in the art. It is shown and described, for example, in Fig. 2 of the prior Lindenblad Patent No. 1,927,522 (Vol. II, p. 486), which was one of

the patents originally in suit, and as to which the District Judge dismissed the bill of complaint, which dismissal was affirmed by the Court of Appeals.[9]

In the next place, the patent is expressly directed and limited to that type of V antenna structure in which principal radiation is effected *only in the plane of the wires* and on the axis or bisector of the V. Thus, if the wires are arranged *horizontally*, then *radiation* is horizontal; if the wires are arranged *at an angle* to the earth's surface, then radiation is *at the same angle*, but always *in the plane of the wires.*

This is made perfectly clear by the patent. Petitioner's expert Kelley pointed out (Vol. I, p. 220, Q389 to p. 223, fol. 318) eleven instances in the patent where, by one form of expression or another, that is what is advanced and described as the precise thing to which the patent is directed and confined.[10] On this the experts of both sides (Kelley for petitioner and Hogan for respondent) were in entire accord (Vol. I, pp. 223, 224, Qs. 395-397).[11] Hogan additionally testified (XQ735, Vol. I, p. 187):

> "The Carter third patent tells how to build a V antenna, which not merely concentrates the energy along the direction of the axis of the system, but *within the plane of the wires in a beam along the line of the bisector.*"*

---

[9] There are numerous other instances of "V" type antennas in the prior art to which reference may likewise be made. For example, see Bethenod French Patent No. 596,737 of 1925 (Vol. II, p. 824), and Levy French patent of addition No. 30,798 of 1926 (Vol. II, pp. 872-873).

[10] See the patent, Vol. II, p. 499, lines 62, 64, 74; p. 500, lines 29, 42, 97; p. 501, lines 71, 86, 110, 124; p. 502, lines 3, 27.

[11] See also Vol. I, p. 121, fol. 177; p. 122, fol. 178; p. 125, fol. 182.

* Italics ours in this brief, unless otherwise stated.

Indeed, the patent states (Vol. II, p. 502, lines 27 *et seq.*) that when it is desired to radiate *at an angle* to the earth's surface it is necessary to tilt the wires from their *normal horizontal position,* to the *required angle to the earth* so that the wires are aimed like a gun, thereby, *at all times,* preserving the essential feature of the patent that the radiated waves be retained in and limited to the plane of the wires and along the axis or bisector of the angle between them.[12]

This express provision of the Carter specifications was not an oversight, or the patent draftsman's error. To the contrary, it was intentional and deliberate. This is conclusively shown by a subsequent patent to Carter (No. 2,027,020, Vol. II, p. 755) which was filed after the construction of petitioner's antennas and issued on January 7, 1936, during the trial of the case. It is in evidence as Defendant's Exhibit U.

In this later patent Carter says with respect to the patent in suit:

> "In my United States patent No. 1,974,387, granted September 18, 1934, there is described a V type antenna arrangement which is adapted to radiate energy directively. This arrangement comprises a pair of linear conductors which are long relative to the length of the communication wave and disposed at an angle in such a manner that when energized radiation occurs *principally along the bisector of the angle*" (p. 755, ll. 3 *et seq.*).

---

[12] The language of the patent is (Vol. II, p. 502, line 27):

> "The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission *it may often be found desirable to have the plane of the wires tilted away from the earth and towards the direction in which the beam of energy is to be propagated.*"

> *"So far, the effects of ground upon the resulting radiation have not been mentioned. In both theory and practice it has been found that the reflections from ground are such as to always result in zero radiation horizontally at the usual communication distances from any short wave antenna. It has also been found that radiation at angles in the neighborhood of 10° to the horizon is most effective at a distance receiver"* (p. 756, ll. 29 *et seq.*).

Thus, the *later* Carter patent constitutes an irrefutable admission by Carter that his patent here in suit, deals *only* with radiations from an antenna *in the plane of the wires*, and the specification of the patent in suit is consistent, from beginning to end, with this admission.

On this the Trial Judge found (Vol. II, p. 1145, fol. 1362):

> "The main object of the three antenna patents in suit was to arrange two or more antenna wires *so that radiation takes place in the plane of the wires horizontally if the wires are horizontal with respect to the ground and at angle if the wires are tilted at an angle.*"

Again, the Trial Judge found (Vol. II, p. 1155, fol. 1378):

> "The third Carter patent in suit deals *only* with horizontal radiation from an antenna *in the plane of the wires and the bisector of the angle.*"

In the face of the foregoing facts, and in the teeth of the testimony of experts on both sides, the Court of Appeals below reversed the Trial Court, saying (Vol. II, p. 1172, fol. 1407):

> "Long distance short wave transmission is *not* carried on by means of signals transmitted horizontally along the surface of the earth; the signals that reach a distant receiving antenna are those which have left

> the transmitting antenna *at a small upward angle* and been deflected back to earth by a portion of the upper atmosphere that reflects radio waves due to the fact that it is conducted because of ionization."

Rather than affording a basis for a reversal of the District Court, this statement of the Court of Appeals emphasizes the soundness of the District Court's conclusion that the patent, which was *expressly* directed and confined to operations "*not* carried on" in long distance short-wave transmission, was purely a paper patent, of no practical value, *and not followed in practice by either respondent or petitioner.*[13]

Thereupon, the Court of Appeals, in a statement diametrically opposite to the finding of the Trial Judge, and completely belied by the patent on its face, as well as by the expert testimony of *both* parties, proceeded to say (Vol. II, p. 1172, fol. 1408):

> "The main consideration is that Carter described a practical directive antenna which is of great commercial utility *when used just as he said it was to be used.*"

Of course, no *novelty* is claimed for Carter in confining the radiated waves to the plane of the wires, even in a V type antenna, because, as appears on their faces, and as found by the Trial Judge, that feature was fully disclosed in the prior antenna patents (the Lindenblad patents originally in suit). Indeed, the Trial Judge, after stating that the main object of all three of the antenna patents was to effect radiation only "in the plane of the wires" (see *ante*, p. 14) found (Vol. II, p. 1145, fol. 1362):

> "The wires are arranged parallel to one another in the first Lindenblad patent in suit and according

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[13] See District Court's decision, Footnote 5, *ante*, p. 6.

to it *the principal radiation is concentrated in the plane of the wires* as distinguished from prior arrangements in which, according to Lindenblad, radiation took place in *other* directions *outside* of the plane.

The purpose of the second Lindenblad patent in suit was to *improve* on the first Lindenblad patent in suit by concentrating radiation *not only in the plane of the wires, but along the axis of the V into which the two wires are formed, which constitutes the bisector of the angle formed by the wires.*

The third Carter patent in suit has as its object to *improve* on the second Lindenblad patent in suit *by achieving an even greater concentration in the plane of the wires along the bisector of the angle by selection of the proper angle between the legs of the V.*"

Thus it will be seen that all that is advanced as Carter's contribution is, as stated by the Trial Judge, the "selection of the proper angle between the legs of the V" at which maximum concentration of radiation *in the plane of the wires and along the bisector* can be effected.

The Angle of the "V".

An examination of the specifications of the patent (Vol. II, p. 499 *et seq.*) reveals that the formula by which the angle of the V is determined is expressed in mathematical equations of trigonometrical function. And, as so stated, either *precisely*, or in *empirical* form, *expressly* forms the subject matter of most of the forty-one claims of the patent, and *impliedly* of all of them. Claims 1, 2, 3, 4, 10, 12, 15, 16, 28, 34, 35, 36, 38 and 40 of the patent (fourteen in all) were put in issue at the trial. Respondent acquiesced in the District Court's finding of non-infringement of all of them except claims 15 and 16, to which two claims its appeal was

confined. These two claims express this mathematical formula in "empirical" form.[14]

In the District Court respondent claimed (through its expert witness) that this mathematical formula was novel with Carter, and, presumably, constituted his invention.[15]

However, respondent conclusively proved that the formula had been devised and published by a well known scientist Abraham more than thirty years before Carter.[16]

In consequence, respondent abandoned its contention made in the District Court, and conceded in the Court of Appeals that there was no element of novelty or invention in the utilization of the Abraham formula, and advanced the *empirical* statement of the Abraham formula as Carter's invention.[17]

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[14] Claim 15 in suit reads as follows:

> "An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice
>
> $$50.9\left(\frac{l}{\lambda}\right)^{-0.513}$$
>
> degrees, l being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length."

Claim 16 merely adds to claim 15 the old "reflector".

[15] Hogan, Vol. I, p. 122, fol. 179.

[16] See Abraham articles, Vol. II, pp. 761-784.
The Trial Judge found (Vol. II, p. 1151, fol. 1372):

> "The mathematical formula advanced as the invention of the patent was copied from the prior art formula of Abraham which had been used by engineers for determining the identical angle for which it was employed by Carter."

Again the Court stated (p. 1152, fol. 1373):

> "The Abraham formula for determining the angle between the legs of the V is copied in the specification."

[17] Further discussion of the Abraham formula will be had later, when considering the prior art (*post*, pp. 43, 49).

Wire Length.

There is but one further point to be considered in connection with the disclosure of the Carter patent. The Abraham formula is *correctly* applicable *only* to antenna wires an integral number of half wave-lengths long. In other words, if an antenna radiates waves of 50 meters, the Abraham formula would be correctly applicable to determine the proper angle of the "V" *only* if the wires are of a length consisting of *an integral number of half wave-lengths,* viz: 50 meters, 75 meters, 100 meters, 125 meters, etc.

From this it will be seen that neither the angle of the V nor the wire length, alone, will determine the direction of principal radiation. It is a *combination* of them which determines it, and it can be determined by the Abraham formula *only* for an antenna wire of a length consisting of *an integral number of half wave lengths.* The Carter patent itself points out (Vol. II, p. 500, lines 61-62) that in the formula

> "The letter 'n' indicates *the number of half wave lengths contained in the wire*"

regardless of whether or not one is dealing with an *odd* number of half wave lengths or *even* numbers thereof. The patent further states (p. 501, lines 16, *et seq.*):

> "The law giving the correct angle for lengths *between* odd and even number of half wave lengths is *not* given herein *due to its complexity* • • •."

In other words, the patent on its face purports to apply the Abraham formula to the *odd* and *even* multiples of half wave lengths *and to nothing in between them.*

Thus, the Carter application, *as originally filed,* was expressly limited in its specifications and claims to antenna wires *an integral number of half wave-lengths long* to which

the Abraham formula (and the empirical formula based thereon) would *correctly* apply. Petitioner, on the other hand, does not use antenna wires an integral number of half wave-lengths long (with the exception of antenna No. 8, which, however, does not use the *angle* prescribed by the formula). In consequence, none of petitioner's antennas employs the angle called for by the Abraham formula, either as originated by Abraham and copied by Carter, or as stated in empirical form by Carter.

Because of this fact (of which respondent was made cognizant by petitioner's answer to the original bill of complaint) the specifications of the then still pending Carter application, as well as the claims, were amended, *after the formal allowance of the application by the Patent Office on June 13, 1934* [18] so as to define the term "plurality of half wave lengths" as meaning an antenna of *any* length—a wholly meaningless thing and entirely inconsistent with the plain language originally employed.

Thus, the Carter specification was amended by adding thereto the paragraph now appearing on page 502, lines 35-42 of the patent, which states, in effect, that by the term "a plurality of wave lengths" or "a plurality of half wave lengths" or "several half wave lengths" not only an *exact* integral number of such lengths, *but also all other lengths*, were meant.[19] A similar amendment was made to substan-

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[18] Vol. II, p. 1109.

[19] The exact language of the amendatory insertion into the patent specification is (Vol. II, p. 502, lines 35 *et seq.*; amendment, p. 1123):

> "By the term 'plurality of wave lengths', or 'plurality of half wave lengths', or 'several half wave lengths', it is not intended that the wires so described shall necessarily be an *exact* or *approximate* integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long *to include* the lengths specified."

tially all of the claims. Original claim 5, for instance (Vol. II, p. 1043) defined the length of the conductors as "substantially a plurality of half wave lengths long." This was changed in the amendment (Vol. II, p. 1123) to read:

> "of a length *including* substantially a plurality of half wave lengths."

There was nothing in the original specifications that warranted such expansion of Carter's disclosure. To the contrary, prior to the revolutionary amendment of the Carter specifications and claims, several of the claims (specifically including claim 15 here in suit, originally numbered as 19) were rejected on the second Lindenblad Patent (No. 1,927,522, Vol. II, p. 486, *et seq.*). In the endeavor to establish a difference between Carter and Lindenblad, Carter stated (Vol. II, p. 1085):

> "It is admitted that the Lindenblad patent is broad and dominates the present arrangement in some respects, but it is submitted the patent *does not show* the relation between the angle and the exact length of antenna as applicant teaches." (Emphasis Carter's.)

Then, again (p. 1104):

> "It is herein repeated that these claims define *a precise relation between the angle and the length of the antenna, which is not to be found in the Lindenblad patent.*"

And, again (p. 1105),

> "Lindenblad necessarily has included in his general conception the thought of a V type antenna, *but he did not include the definite precise relation between the angle and the length of the antenna for giving the best results.*"

As to this the Trial Judge found (Vol. II, p. 1145, fol. 1363) that the Carter patent distinguished from Lindenblad only by

> "selection of the *proper* angle between the legs of the V".

The Trial Court further found (Vol. II, p. 1146, fol. 1364) that

> "Carter's formula is predicated upon the *precise* relation between the angle of propagation and the *exact* length of the antenna wires, which *must* be an integral number of half wave lengths in order to be accurate."

Therefore, not only was the Carter patent deliberately and intentionally confined, as originally filed, to the *precise* angle and *exact* wire length, but it was known to Carter, and admitted in his file wrapper, that it was *only* by that *precise* relation that he differed from the prior Lindenblad patent.

Thus, Carter's claims were allowed as a result of these express representations to the Patent Office. *After the formal allowance of his application,* however, and as a result of oral interviews had with the Examiner, to which reference is made in the file history (Vol. II, pp. 1124, 1125), the claims, procured by his plea and admission that his *invention* was for this limited, *precise* thing, were changed and are *now* advanced as *not* limited to the *precise* angle, but covering *a wide range* of angles; and *not* limited to antenna wires having an *exact* length consisting of an integral number of half wave lengths, but to *all* wires *regardless of their lengths.*

The Opinion of the Court of Appeals on this Point.

The Court of Appeals quite erroneously stated, referring to wires several half-wave lengths long:

> "Carter found that interpolation between these lengths was sufficiently accurate for practical purposes and disclosed the angles to use for V antennas using wires of *intermediate* lengths." (Vol. II, p. 1173, fol. 1408.)

Not only does the Carter patent contain no disclosure of such angles, but it is admitted in his patent (Vol. II, p. 501, line 16 *et seq.*):

> "The law giving the correct angle for *lengths between* an odd and even number of half wave lengths is *not* given herein *due to its complexity.*"

This is followed by the statement in the patent that for all practical intents and purposes the *empirical* formula will be found accurate enough. Petitioner answered this by evidence which conclusively proved that for intermediate lengths *neither the Abraham nor the empirical formula,* but a wholly different formula is applicable. The difference was graphically illustrated in Defendant's Exhibit X, Vol. II, page 821. Moreover, this subject was thoroughly covered by the experts of both sides, and the Trial Judge, after weighing all of the evidence bearing on the subject, found (Vol. II, p. 1555, fol. 1377):

> "The two Abraham formulae are applicable *only* to wires an *exact* number of wave lengths long. It is true that in Fig. 12 of the patent Carter drew a smooth curve which apparently includes all lengths of wire between the half wave lengths *but I am convinced that neither Carter's empirical formula nor Fig. 12 make a correct showing of what happens when the wires are other than exact multiples of half wave lengths.*"

Summary.

Thus, the Carter patent is directed—

(1) *to a V antenna structure* (concededly old in the art),

(2) *in which radiations are confined to the plane of the wires and on the axis or line bisecting the V* (concededly old in the art, and of no utility, being employed by no one, not even by respondent);

(3) *the exact or precise angle of the V at which the maximum of such radiation would be effected being determined by a mathematical formula* (literally copied by the patentee from the Abraham publication);

(4) *empirically stated* (as within the province and capability of any engineer).

The patent thus obtained not only differed radically in material and essential respects from the application for patent as originally filed, but was inconsistent and contrary thereto, as well.

This, then, is the patent by which respondent endeavors to blanket the public service world-wide radio telegraph field, and eliminate competition therein.

POINT I.

The Carter patent is not infringed.

Petitioner employs the old V-type antenna structures. Eleven of its antennas are charged to infringe. There are a number of features incident to them which take them completely out of the Carter patent. These are:

1. None of petitioner's antennas is designed to or in fact radiates *in the plane of the wires.* On the contrary,

petitioner's antennas *intentionally* radiate *at a substantial* angle to the plane of the wires, for the *deliberate* purpose of utilizing the reflective effect of the Heaviside layer. (Pratt, Vol. I, p. 203, fol. 289; Kelley, Vol. I, Qs. 292-295, pp. 208-209; XQ1089, p. 273).[20]

Thus, Mr. Pratt, petitioner's Chief Engineer, who designed and supervised the erection of all of petitioner's antennas, stated (Vol. I, p. 203, fol. 289):

> "Referring to the antennas Nos. 1 to 11 at Sayville, *I do not know of any case where radiation is propagated predominantly in the plane of the wire.*"

Likewise, petitioner's expert Kelley testified (Vol. I, p. 208):

> "Q292. Referring to defendant's antenna, in the case of any antenna employed by defendant, is the propagation of the radiant energy predominantly in the plane of the wires? A. No, sir, *the radiation is sent out at a considerable angle, a substantial angle, to the plane of the wires.*"
>
> "Q293. Is that accomplished accidentally or as a matter of design? A. *That is accomplished as a matter of design.*"
>
> "Q295. What is the purpose of propagating the radiant energy from defendant's antennas at an angle to the plane of the wires? A. The purpose is to make use of what is known as a sky wave so that, as is well known in short wave radio systems, the energy can be reflected from the upper ionized layers of the atmosphere, and consequently sent to great distances."

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[20] The Heaviside layer is a region of ionized atmosphere of from 100 to 200 miles from the earth's surface.

2. None of petitioner's antennas propagates its main lobe of radiation *on the axis or bisector of the angle of the V.*

3. None of petitioner's antennas (with the exception of antenna No. 8) uses wires *an integral number of half wave-lengths long,* as was originally specified by the Carter patent. On the contrary, petitioner's radiator wires depart from the half wave-length measure as far as it is possible to do so.[21]

4. None of petitioner's antennas utilizes an angle between the legs of the V that is dependent upon the Abraham formula, either as originally stated by Abraham or as restated by Carter in empirical form. This especially applies to petitioner's antenna No. 8 above referred to. The application of the foregoing statement to the remainder of petitioner's antennas will be made evident by the consideration that the formula is predicated upon the *precise* relation between the angle of propagation and the *exact* length of the antenna wires, which *must* be an integral number of half wave-lengths in order to be correct, and which petitioner does not employ.

Because of the foregoing *facts* with respect to petitioner's antennas, which were conclusively established by the evidence—including testimony of experts and engineers as well as by documentary proofs—and which, in the main,

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[21] See Plaintiff's Exhibit 13, Vol. II, p. 530, the stipulated specifications of petitioner's antennas. It will be noted in the marginal heading "Length of one V Wire" the wire length is given expressed in wave lengths. In each instance, with the exception of antenna No. 8, the wire lengths are almost exactly a quarter wave length longer or shorter than a multiple of an even or an odd number of half wave lengths. In other words, petitioner's antennas depart from a multiple of half wave lengths *as far as is physically or mathematically possible.*

was not disputed by respondent, the Trial Judge made the findings reproduced in part in footnote 4, *ante*, page 5.

It is unthinkable that a "paper" patent, unused by anyone, could be adjudged to be infringed by any of petitioner's highly efficient commercial antennas.

Opinion of the Court of Appeals on this Point.

Contrary to all of the foregoing, the Court of Appeals described the antenna of the Carter patent as follows:

> "This antenna consists of one or more pair of long, straight, unmodified wires, placed at a *preferred* angle" (Vol. II, p. 1168, fol. 1402).

From what has been said above, the error of the Court will be manifest. The patent does not even pretend to be for a V antenna having a *preferred* angle. It is for so *precise* an angle that it can be defined only by a mathematical formula. Indeed, the statement of the Court of Appeals is expressly belied by Carter himself (as hereinbefore pointed out, *ante*, p. 20) in inducing the Patent Office to grant a patent to him over Lindenblad.

Having thus construed the Carter patent the Court proceeded to find infringement in the face of the fact that *it was conceded that petitioner's antennas did not employ the precise or exact angle obtained by the Abraham formula.* The Court did this with the assertion that petitioner's antennas used "substantially" the angles determined by the formula, even including within its holding antenna No. 8 *which departed therefrom as much as ten per cent.* Indeed, in one instance (Vol. II, p. 1171, fol. 1405), the Court held that petitioner had utilized "*substantially the exact*" angle specified by Carter, whatever that expression might mean.

Notwithstanding the fact that the patent was expressly obtained for a *prècise* angle, the Court of Appeals has given it an interpretation by which it covers a wide and apparently unlimited *range* of angles. Such an interpretation of the patent inevitably necessitates its invalidation by the Lindenblad V-antenna patent alone, which, because it fails to specify *any* angle, inescapably discloses a *range* of angles.

In addition to the foregoing, the Court of Appeals held (Vol. II, p. 1172, fol. 1408):

> "Most of appellee's antennas do not use wires that are of integral number of half wave lengths *but that does not avoid infringement.*"

It is believed that this holding, on which its conclusion was in part, if not wholly based, is so palpably erroneous in view of what we have hereinbefore pointed out as to require no further comment.

POINT II.

The Court of Appeals below reversed every essential finding of fact made by the Trial Judge on the conflicting evidence before him, without reference to the evidence or even mention thereof.

This Court, in *Adamson* v. *Gilliland,* 242 U. S. 350, at page 353, stated the "rule", particularly applicable to patent cases, to be:

> "• • • so far as the Master or Judge who saw the witnesses 'depends upon conflicting testimony or upon the credibility of the witnesses, or so far as there is any testimony consistent with the finding, it must be treated as unassailable'."

We can conceive of no case to which this rule should be more applicable than to the present one. The subject matter of the suit is extremely technical, involving abstruse theories of scientific principles expressed in mathematical formulae, derived from differential and integral calculus equations and expressed in terms of trigonometric function. The trial involved five patents directed to various highly scientific phases of the subject matter, and lasted nearly a month, during which time more than a score of witnesses were examined and cross examined. They included experts for both sides, whose knowledge, experience, and other qualifications were unquestioned by either side, and was demonstrated by the thoroughness and care with which they discussed the subject matter of the suit.

As a result, and based on his study of the prior art explained to him, also on his seeing and hearing the witnesses testify, as well as on the careful scientific preparation, definition and exposition of the technical issues presented for decision, the Trial Judge made findings of fact expressed in his opinion, and accepted by both sides, by stipulation, as such.

These findings include:

(1) That the Carter patent in suit:

> "is expressly limited as to some claims, and impliedly as to all thereof, to *radiation in the plane of the wires* and, in fact, on the line bisecting the angle between the legs of the V" (Vol. II, p. 1153, fol. 1375).

And, again, that:

> "The third Carter patent in suit deals *only* with horizontal radiation from an antenna *in the plane of the wires* and the bisector of the angle" (Vol. II, p. 1155, fol. 1378).

(2) That—

> "The defendant's antennas which are charged with infringement *differ radically* from the inventions claimed in the three antenna patents in suit" (Vol. II, p. 1145, fol. 1363).

And that

> " • • • all of the defendant's antennas are intentionally designed to cooperate with ground effect, which effect not only is not contemplated by any of the patents in suit but is *contradictory* to the description and claims thereof" (Vol. II, p. 1146, fol. 1364).

The Court also found:

> "Due to the *departure* from the Carter patent in the respects enumerated and by reason thereof in all of defendant's antennas here charged to infringe, defendant obtains material advantages and increased efficiency in that material increase in radiated power is obtained" (Vol. II, p. 1151, fol. 1372).

Again,

> "Defendant does *not* radiate in the plane of the wires • • • " (Vol. II, p. 1153, fol. 1375);

and

> "As I have hereinbefore stated, defendant's V antennas radiate at an angle to their planes and to their bisectors, and this is *contrary* to Carter's teachings" (Vol. II, p. 1155, fol. 1378).

Also—

> " • • • the fact is, however, that defendant's systems are *radically different* from the patents in suit, in structure, principle of operation and instrumentalities, and were designed and constructed to secure

and did secure greater radiation, *by reason of such difference,* than could be obtained by the patents in suit" (Vol. II, p. 1157, fol. 1380).

(3) That the Carter patent is confined to the *precise* angle of the V antenna, and only in that respect did it purport to differ from the prior Lindenblad V antenna patent which, concededly, was of the prior art. The Trial Judge found:

> "The Lindenblad patent does not show the relation between the angle and *exact* length of the antenna as Carter teaches, and in the claims as amended he defines the *precise* relation between the angle and the length of the antenna. The defendant does not use the *precise* relation of the Carter patent, and, in view of the Lindenblad patent, Carter could not obtain claims to cover a *range* of angles. All of defendant's antennas differ from the angle specified by Carter, and while the difference is not great, it is as great as the difference between Bruce (of the prior art) and Carter. If defendant's antenna No. 8, where the angle is differed 10% from Carter, infringes, then Lindenblad anticipates" (Vol. II, p. 1156, fol. 1379).

(4) That the statement and claim of invention of the Carter application as originally filed was altered and broadened by amendment in the endeavor to claim as the invention something which was not only *not* originally disclosed, but which was inconsistent with and contrary to what *was* originally disclosed. The Trial Judge found:

> "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well" (Vol. II, p. 1154, fol. 1377).

In making this finding it was necessary for the Trial Court to consider the technical and practical definition

of terms and phraseology employed in the Carter application as filed, and in the Carter patent as issued, as well as the proper and intended meaning of those terms addressed to the man skilled in the art. For example, it was necessary for the Court to weigh, in the light of the conflicting evidence directed thereto, respondent's contention that the Abraham formula, empirically stated, could be correctly applied to wires of a length other than exact multiples of half wave-lengths. As a result the Trial Judge found:

> "* * * but I am convinced that neither Carter's empirical formula nor Fig. 12 make a correct showing of what happens when the wires are other than exact multiples of half wave-lengths" (Vol. II, p. 1155, fol. 1377)."[22]

As another example, it was necessary for the Trial Judge to determine whether or not the statement contained on the face of the Carter patent (Vol. II, p. 499 lines 29-34) to the effect that the invention was applicable to wires of "any finite length", which statement was added to the specification by amendment after the commencement of the present suit, meant the same thing as a statement employing the word "finite" made in the application as originally filed (Vol. II, p. 1032), and which was thereafter canceled on May 2, 1934 (Vol. II, pp. 1092, 1093).

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[22] "Fig. 12" here referred to is Fig. 12 of the drawings of the Carter patent which purports to be merely a curve drawn through points plotted on graph paper so as to connect more or less smoothly the points determined by the Abraham formula. This is made quite clear from the patent specification (Vol. II, p. 500, lines 78 *et seq.*) where it is stated:

> "Obviously the critical value of θ for either of the above equations may readily be determined; its value for wires up to fourteen wave lengths long is given graphically in Figure 12."

As a result of the extensive exposition of these questions by both sides, and after weighing the conflicting testimony on the issue, the Trial Judge stated:

> "I do not agree with plaintiff's contention that the original specification warranted such extension of Carter's disclosure" (Vol. II, p. 1154, fol. 1376).[23]

Again, the Trial Judge said, this time with *express* reference to the use of the term "finite length" in the passage above referred to, appearing on the first page of the patent as issued:

> "Even this passage was added in the amendment of May 2, 1934, and after the commencement of this action" (Vol. II, p. 1155, fol. 1377).

(5) Finally, that the patent in suit was directed (as were, likewise, the other two antenna patents originally in suit) to a theory not followed in practical communications, and that the alleged invention thereof had never been employed by anyone, not even by respondent. The Court found:

> "In substance all of the antenna patents in suit present merely a theoretical application of antenna wires in free space, whereas all of the defendant's are intentionally designed to cooperate with ground effect, which effect not only is not contemplated by any of the patents in suit, but is contradictory to the description and claims thereof." (Vol. II, p. 1146, fol. 1364.)

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[23] It should be noted that in passing on the issues of validity and infringement of the *other* patents in the case it was necessary for the Court to thoroughly understand this language. See, for example, the opinion of the Trial Judge on the *other* patents (Vol. II, p. 1135, fol. 1348).

Also, the Trial Judge found:

> "None of the patents in suit are pioneer patents, as contended by plaintiff, and the record does not show that they have been employed by any one; even the plaintiff's own commercial structures do not follow the teachings or employ the instrumentalities shown, described or claimed in any of the patents in suit, as I have interpreted the same." (Vol. II, p. 1156, fol. 1380.)

The Court of Appeals reversed each and every one of these findings of fact without reference to or even mention of the evidence on which the Trial Judge's findings were predicated, and without pointing to any error on the part of the Trial Judge on which to base a contrary finding.

It cannot be questioned but that each and every finding of the Trial Judge is based on competent testimony with which the finding is "consistent". As to some of the points, the testimony stands either unchallenged or expressly accepted; as to others, conflicting testimony by the experts of both sides raised issues of fact which the Trial Judge resolved, both upon the "conflicting testimony" and upon the "credibility of the witnesses". The findings of the Trial Judge, therefore, should have been treated as "unassailable", and the Court of Appeals committed error in failing to do so.

POINT III.

The patent is invalid because of the unlawful amendment thereof, made in the endeavor to mold the patent as to disclosure and claims so as to cover petitioner's antenna systems, and which amendment was contrary to the original statement and claim of invention.

This suit is an outstanding example of that class of cases, so frequently met with, where an inventor (or more often his assignee) by means of a pending patent application seeks to keep abreast of the art and dominate that art by means of amendment, modification, and re-statement of invention and claim wholly inconsistent with the usually worthless application originally filed. The result is that a patent issues, not for the invention for which the inventor made application, but for something wholly foreign to and, as in this instance, wholly inconsistent with the alleged invention originally presented.

This Court said many years ago, in *Chicago & N. W. Railway Co.* v. *Sayles*, 97 U. S. 554, 563, in invalidating the patent then before it on this ground:

> "The law does not permit such enlargements of an original specification, which would interfere with other inventors who have entered the field in the meantime, any more than it does in the case of reissues of patents previously granted. Courts should regard with jealousy and disfavor any attempts to enlarge the scope of an application once filed, or a patent once granted, the effect of which would be to enable the patentee to appropriate other inventions made prior to such alteration, or to appropriate that which has, in the meantime, gone into public use."

> See, also, this Court's recent decision (rendered Nov. 7, 1938) in *The Schriber-Schroth Co.* v. *The Cleveland Trust Co., et al.*

In a case involving this same question, the Court of Appeals for the Third Circuit in *Lopulco Systems Inc.* v. *Bonnot Co.*, 24 Fed. (2) 510 (cited with approval by this Court in *Powers-Kennedy Contracting Corp.* v. *Concrete M. & C. Co.*, 282 U. S. 175, 186) said:

> "The duty of careful scrutiny in such cases was referred to by this court in Hestonville v. McDuffee (C. C. A.) 185 F. 802, where it was said: 'when, therefore, a patentee, seven years after his original application'—in the instant case two years—'and enlightened by such intervening years of progress, seeks not to prosecute his original application, but to amend the same, and on the basis of such amendment to make claims of a different character from those originally made, it becomes the duty of a court to zealously and jealously scrutinize such belated application'."

See also *Irving Air Chute Co.* v. *Zwitlik Parachute & Equipment Co.*, 82 Fed. (2) 644 (C. C. A. 3rd).

It follows, therefore, that the Carter patent is invalid on this ground.

We are not unmindful of the fact that claims 15 and 16, to which the case is now confined, were, in substantially the same form, in the application as originally filed. It is elementary, however, that a patent claim must be construed in the light of the invention described in the specifications. Claims 15 and 16, as originally filed, could *not* have been construed as applying to antennas of any length other than an integral number of half wave-lengths. It is equally as elementary that if the patent is invalid because of unlawful amendment, no claim of the patent can survive. Obviously, it is just as fatal to unlawfully expand the statement of

invention so as to permit an otherwise innocuous claim to cover something without the compass of the invention, as it is to expand the claim itself so as to accomplish that result.

POINT IV.

The patent is invalid because the amendment, which broadened its disclosure and claims contrary to their original terminology and spirit, was not subscribed to or supported by the oath of the inventor as prescribed by the patent statutes.

Section 4888 of the Revised Statute [24] prescribes *as a condition to the grant of a patent,* that the inventor must subscribe to the application for patent and the claim he seeks. The pertinent words of the statute are:

> "The specification and claim *shall* be signed by the inventor."

This is mandatory, and a statutory prerequisite to a valid grant.

In addition, Section 4892 [24] requires, as a prerequisite to the patent grant, that the inventor make oath that he believes himself to be the original and first inventor of the invention "for which he solicits a patent".

The Carter application, as originally filed, defined and claimed the invention as comprising the determination of the *precise* angle of the wires constituting the V antenna, and, quite correctly, that it was obtainable *only* with wires an integral number of half wave-lengths long. That original application was signed and sworn to by Carter, the applicant. The amendment to the claims which endeavored

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[24] See Appendix, p. 53.

to cover *all* antenna wires regardless of their length, in the effort to include petitioner's antennas within their scope [25]—viz: the amendment which directed the patent to a *different* and wholly *inconsistent* invention—was *never* subscribed or sworn to by the inventor.

The Court of Appeals, in *Westinghouse E. & Mfg. Co.* v. *Metropolitan E. Mfg. Co.*, 290 Fed. 661, 664, said, with respect to Section 4892 R. S.:

> "That statute requires that one shall swear to his invention, and all of it; if he only swears to a part, and his attorney puts in the rest, it is exactly like any other yielding to the temptation of improving an affidavit after execution, by inserting additional allegations of fact. A claim is not a disclosure; but every claim must be justified by the disclosure. If, therefore, a new claim needs for its justification or validity an additional or new disclosure, such additional allegations of fact assuredly need a supplemental oath, not because they are to be used for an amended or new claim, but because they tell some fact of invention not told before."

We submit as obvious, therefore, that the Carter patent is invalid because it issued for an invention radically different from that for which application for patent was made, and the claim of invention, as amended, was neither subscribed to nor supported by the oath of the inventor—a statutory prerequisite to its valid grant.

The Opinion of the Court of Appeals on this Point.

Notwithstanding the fact findings on this point by the Trial Judge, the Court of Appeals, because Carter had used the word "finite" in his application as originally filed,

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[25] Amendment of August 4, 1934, Vol. II, p. 1122.

found that it was his intention to cover antenna wires of *any* length, as distinguished from the *exact* length consisting of an integral number of half wave lengths.

The only passage in Carter's application as originally filed in which the expression "finite" occurs is as follows (Vol. II, p. 1032):

> "Still a further object of the present invention is to disclose the proper angle for conductors or radiators *either an even number of half wavelengths long or an odd number of half wavelengths long,* and, in general to disclose the angle for best directional propagation for wires of *any finite length.*"

If this passage were construed to cover every possible length of wire, then the meticulous reference to conductors of an even number of half wave lengths and an odd number of half wave lengths would lose all meaning.

However, "finite" means the opposite of "infinite", and these terms have a very specific meaning in this art. As expounded by the experts and discussed by the Trial Judge in connection with the *other* patents that were before him, "standing waves" are produced if the wires have a "finite" length, and "traveling waves" if the wires are "infinitely" long.

The electrical characteristics of a wire may be so altered that it behaves the way a physically "infinitely" long wire would behave. Such electrically infinitely long wires would be used in a traveling wave antenna.

As distinguished from this, the Carter patent (see the first full paragraph on the same page of the application, Vol. II, p. 1032), had to do *only* with antennas in which "standing waves" are produced. Only thus could Carter differentiate from many prior antennas, including the one discussed

in the Lindenblad Patent No. 1,927,522, in which "traveling waves" are produced.

To produce standing waves the antenna wires must be of a "finite" length. It is clear, therefore, that in the quoted passage Carter merely meant to warn that the wires must not be physically or electrically extended to produce traveling waves.

Wholly aside from the technical meaning of the word "finite", could it be assumed that Carter in writing this passage had in mind all lengths? Obviously not, because then he would not have spoken in the same sentence of wires an even and an odd number of wave lengths long. If there were any doubt on this score it can be resolved by what happened later: When respondent discovered that none of petitioner's antennas satisfied the requirements of the then still pending Carter application, it erased this paragraph and, on May 4, 1934, substituted therefor (Vol. II, pp. 1092-3), the paragraph which will now be found in the Carter patent (Vol. II, p. 499, lines 29-34), and which reads as follows:

> "Another object of the invention is to disclose the angle for the best directional propagation for open-ended wires of any finite length, preferably longer than the operating wave length, having standing waves thereon and arranged in the manner proposed."

There is no reference in this paragraph to wires an even or an odd number of wave lengths long, and this passage clearly covers the lengths of petitioner's antennas. The Trial Judge so held (Vol. II, p. 1155, fol. 1377), but gave it no weight, because the passage was interpolated by respondent *after the commencement of the present action*, and without there being any justification for it in the application as first filed.

POINT V.

The Carter patent is invalid because it is completely anticipated by and devoid of patentable novelty over the prior art.

Before taking up a specific consideration of the prior art we desire more fully to explain the so-called reflector effect.

Reflector Effect.

As previously pointed out (*ante*, p. 9) a reflector is a second antenna which cooperates with the antenna proper so as to cancel radiation in one direction, and reinforce it in the other, as well as to concentrate it into a beam.

The antenna and the reflector, referred to as the first and second antenna, must be properly spaced from one another.

There is no dispute that spacing of a reflector with respect to the radiator to obtain a unidirectional effect was old in the art.

Carter himself recognized the obviousness of the juxtaposition of a reflector with the V-antenna and characterized it as "well known" in the description that accompanied his letter to Mr. Tunick, his patent solicitor, dated May 9, 1930 (Vol. II, p. 666).

In spite of the fact that the First Carter patent and the First Lindenblad Patent (No. 1,884,006, Vol. II, p. 470, *et seq.*) show this even then old expedient, and in spite of the fact that in the I.R.E. article (Vol. II, pp. 589, 590) Carter, Hansell and Lindenblad describe the spacing of a reflector from a radiator as of the "*usual*" kind, we find that claim

16 of the Carter patent covers this identical spacing of a second antenna or reflector.

As we understand it, respondent's position is that while the reflector spacing is the same in the Carter patent as in the prior art, the *combination* of this old feature with the determination of the *precise* angle of the V amounts to invention, although the purpose, function, method of adjustment and installation are exactly and always the same.

Assuming, for the sake of argument, that the V-shaped arrangement of the radiator wires in the Carter patent were new, claim 16 could be sustained only by showing that the *combination* produced a *new and unexpected result* that one skilled in the art could not foresee.

Mills (Vol. II, pp. 878-880) published the rule of reflector effect in 1917 as of general application for *any* combination of antennas. Carter filed his first application (Vol. II, p. 463) in 1923 showing two types of antennas to which the Mills rule was applied. Lindenblad filed an application in 1928 (Vol. II, p. 477) in which he disclosed a different type of antenna, and there also the inflexible rule was applied just as stated by Mills. Carter then filed another application in 1930 (for the patent in suit), with still a different arrangement of antenna wires, and here again the rule applied.

Hogan described (Q76, Vol. I, p. 126) the spacing of the reflector in the Carter patent in suit in the same language which he used in connection with the First Carter Patent (No. 1,623,996). The effect of such arrangement was also well known. Hogan said (XQ304, Vol. I, p. 164):

> "the cancellation in the rearward direction produced by the arrangement of two vertical antennas, for example, the quarter wave separation, and excited in quadrature, as you expressed it, did exist and was known prior to the application for this patent."

The reflector formula is employed by Carter in the same manner as it has always been employed, and in every instance, no matter what the shape or arrangement of the radiator may be, the reflector is arranged parallel with it, and contains the same arrangement of wires. Not one word of testimony was offered by respondent to indicate that any particular problem was involved in this application of the well known reflector formula, or that the result obtained differed in any respect from what one would expect.

In consequence, regardless of all other issues in the case, claim 16 of the patent, which on its face differs from claim 15 only by adding to claim 15 a second antenna as a reflector to thereby make the claim for an alleged *combination* of angle determination and reflector, is invalid.[26]

> *Lincoln Engineering Co.* v. *Stewart-Warner,* 303 U. S. 455;
> *Powers-Kennedy Contracting Corp.* v. *Concrete M. & C. Co.,* 282 U. S. 175.

With the foregoing introduction we now take up a consideration of the prior antenna art.

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[26] Claim 16 of the Carter patent adds the reflector feature to claim 15 by the words:

> "and, a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors".

It is interesting to note that in the first Lindenblad patent originally in suit (No. 1,884,006) claim 26 (Vol. II, p. 484), one of the claims in suit, similarly differed from claim 25, also in suit, by the addition to claim 25 of the words:

> "a similar pair of conductors are provided, the conductors of said similar pair being arranged parallel to the respective conductors of the first pair whereby the directional effect of the system is augmented".

The Abraham 1898 and 1901 Articles (Vol. II, pp. 761-784).

As we have seen, Carter's alleged contribution over the Lindenblad Patent No. 1,927,522 was the ability to determine the *exact* value of the angle of the V. The formula for determining this is old with Abraham who was dealing with the very problem which was before Carter, namely, the direction of radiation from an antenna. Abraham's article of 1898 (Vol. II, p. 768) contains the formula which occurs on page 2, lines 60 and 70 of the Carter patent (Kelley, Vol. I, Q414, p. 229).

In the 1901 Abraham article (Vol. II, p. 777) the same formula is given, and this time it happens to be for the field strength rather than for the power, that is to say, it is in the *same* form as given by Carter, *and Abraham, like Carter, uses the Greek letter Theta to designate the angle.*

Kelley pointed out that there is no difference between Carter and Abraham, either in expression, meaning, significance or application (Qs. 425-432, Vol. I, p. 235). Carter merely copied Abraham's formula.

There was no denial of or rebuttal to this evidence.

Not only Abraham's formula but his general principle of considering the problem is used *in toto* by Carter, the text in the patent being merely a paraphrase of the Abraham articles.

In answer to Q435, Vol. I, p. 237, Kelley pointed out that the empirical equation given in line 85, page 2 of the third Carter patent, and in claims 15 and 16, is obtained merely by plotting the Abraham formula, and he summarizes (Q434, Vol. I, p. 237):

> "the empirical formula comes from this, having drawn a curve, smooth curve, through these points, in other words, disregarding whether or not anything

> happens in between these points to which the formula doesn't apply, but merely drawing a smooth curve through these points, then by methods well known to engineers, deriving a curve, an equation, rather, which fits the curve as near as possible, practically. And the result of that is the empirical formula given on page 2, line 85."

Every engineer knows how to work out an empirical formula from a general formula such as is given by Abraham.

French patent to Bethenod of 1925
No. 596,737 (Vol. II, p. 824).

Kelley pointed out (Vol. I, pp. 245 *et seq.*), that this patent discloses a short wave directional antenna system, consisting of linear conductors a plurality of half wave lengths long.

The conductors may be arranged parallel to each other or, as expressly stated, *inclined at an angle to each other,* that is, in the form of a V.

The patent states (Vol. II, p. 826) that the antenna wires may be

> "inclined not only with respect to the ground, *but also with respect to one another* so as to obtain *directional* effects either *in the horizontal plane,* or in the vertical plane, or in both planes."

Since the angle must be chosen in accordance with the well known Abraham formula to insure best radiation in the desired direction, one skilled in the art, reading Bethenod's instructions, would obviously employ it. There is, therefore, no patentable difference between Carter and Bethenod.

French patent to Bethenod of 1927 No. 625,293 (Vol. II, p. 828).

Kelley's testimony as to this patent will be found in Vol. I, pp. 247 *et seq.* The patent states:

> "The object of the present invention is an antenna arrangement which is particularly advantageous in communicating by means of short waves."
>
> • • • • • • • •
>
> "The portion B, C of the antenna *may form an angle d of any value from 0 to 90° with the horizontal.*"
>
> • • • • • • • •
>
> "In order to obtain the greatest radiation efficiency for the antenna, the length of B, C should preferably be equal to *a whole number of half wave lengths.*"

Kelley showed (Q464, Vol. I, pp. 248 *et seq.*) that this reference contains the same teaching as the Carter patent.

French patent to Levy No. 593,570 of 1925 (Vol. II, p. 862) and the addition thereto No. 30,798 of 1926 (Vol. II, p. 867).

Kelley first discussed the patent of addition (beginning at Vol. I, p. 250) pointing out that it discloses a short wave directional type antenna system in which the wires of the V are in a *horizontal* plane, open ended, and of opposite polarity—hence of the *standing wave* type of the Carter patent.

Kelley's discussion of the original patent is found at page 251, and he there points out (quoting from the patent) that its teaching and the antenna structures therein shown and described are, in all essential respects, the same as defendant's antennas. Kelley, in answer to Q474 (p. 252)

quoted at length from the middle of page 2 of the translation of this patent (Vol. II, p. 862), and pointed out that its language explains the directional radiation that is obtained from petitioner's antennas as clearly shown in Exhibits S and T (Vol. II, pp. 745, 746).

As both Kelley [27] and Pratt [28] testified, in all of petitioner's antennas radiation is propagated at a substantial angle to the horizontal so as to impinge at the correct angle on the Heaviside layer. This is the deciding factor in the directional characteristics of petitioner's antennas. In this respect petitioner departs from the teachings of the Carter patent in suit, and follows the teaching of Levy. This teaching of Levy is emphasized by his summary of Patent No. 593,570 (Vol. II, p. 864), where he states:

> "A method for long distance transmission of Hertzian radiant energy, characterized by:
>
> (1) The transmission of horizontal electric field waves *to favor the reflection without loss on the Heaviside layer and on the ground* and the propagation through space.
>
> (2) The energy transmitted presents a maximum in the vertical plane perpendicular to the axis of the radiator.
>
> (3) The energy is transmitted *in the form of an inclined pencil* accepting as the plane of symmetry the vertical plane perpendicular to the axis of the radiator".

This is a complete definition of the directional radiation that is obtained from petitioner's antennas as clearly shown in Exhibits S and T (Vol. II, pp. 745, 746).

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[27] Vol. I, Qs. 292-298, pp. 208, 209.

[28] Vol. I, p. 203, fol. 289.

The Carter patent is invalid in view of the Lindenblad V Antenna patent alone.

As we have hereinbefore pointed out (*ante*, p. 20) the alleged improvement of Carter over the Lindenblad patent, as expressly asserted by Carter in his file wrapper (in the endeavor to overcome the Lindenblad patent cited by the Examiner of the Patent Office as an anticipation) consisted *solely* of the application of the old Abraham formula to determine the *precise* angle of the old V.

Since V antennas were old in Lindenblad, as well as with others, and since the art knew that the wires of the antenna *must* be arranged in accordance with the Abraham formula for best radiation, regardless of the manner in which they are arranged with respect to each other, the Carter patent is devoid of any novelty or patentable subject matter.

Prior Invention by Bruce.

There was another defense raised in the District Court which consisted of prior invention by an engineer named Bruce, employed by the American Telephone and Telegraph Company. Bruce's work antedated the Carter patent by many years. Because the Carter patent is so obviously invalid for the reasons already discussed, and, regardless of its validity, is so foreign to petitioner's antennas, no specific mention of Bruce's prior invention was made in the petition for writ of certiorari. In consequence, no specific consideration of Bruce's work will be here undertaken, notwithstanding the fact that reference thereto was made in respondent's memorandum in opposition to the petition for writ of certiorari.

However, it should be noted that Bruce's work was established in detail by contemporaneous documentary records, by four engineers of the Telephone Company (besides Bruce himself), and as a result the Trial Judge, in finding want of infringement in the case, accepted Bruce's work as constituting "prior art", stating (Vol. II, p. 1156, fol. 1379):

> "All of defendant's antennas differ from the angle specified by Carter, and while the difference is not great, it is as great as the difference between Bruce (of the prior art) and Carter."

The Court of Appeals, again without reference to the record, lightly waived aside Bruce's work as "abandoned efforts" in the face of the fact that it was as a result of this work of Bruce that the highly efficient trans-oceanic radio telephone antennas of the American Telephone and Telegraph Company, in commercial use today in the principal countries of the world, resulted therefrom.

Summary as to Prior Art.

It is submitted that the prior art above reviewed establishes beyond question that the Carter patent was completely anticipated by and devoid of any patentable novelty over the prior art.

The Opinion of the Court of Appeals on the Prior Art.

The Court of Appeals ignored the anticipating effect of the prior Lindenblad V antenna patent as well as the other prior patents.

With respect to the Abraham articles, the Court of Appeals stated (Vol. II, p. 1174, fol. 1411):

> "The Abraham articles of 1898 and 1901 with the formula *suggested*, although 30 years old, *had never been utilized. From that time was the entire period of the development of the radio art.* While his formulas unquestionably had useful scientific interest to radio engineers, *they failed to teach how to construct a directive antenna.*"

The Abraham articles did not merely *suggest* the formula—*they gave the exact formula that Carter copied.* Moreover, this formula is not merely a matter of scientific curiosity. Plaintiff's Exhibit 20 (Vol. II, p. 538), the I. R. E. article written by Carter and his associates, Hansel and Lindenblad, specifically refers to Abraham's work, which was, in fact, utilized by them in the antenna operations therein described.[29] Not only do these facts completely expose the error on the part of the Court of Appeals, but *there is not one word of evidence in the record to support the Court's wholly erroneous assertion that the Abraham formula "failed to teach how to construct a directive antenna".* The evidence is directly to the contrary.

Additional Comments on the Opinion of the Court of Appeals.

While elsewhere herein we have made comment on specific statements in the opinion of the Court of Appeals, in connection with our discussion of the specific subject matter to which those portions of the opinion were directed,

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[29] In addition, reference to the first Lindenblad patent No. 1,884,006 (Vol. II, p. 470) shows the angle of predominant radiation from the antenna wires identified by the Greek letter alpha, which respondent's expert admitted corresponded to the angle determined by the formula of the Carter patent, and which, in turn, as we have seen, and is now admitted, is the Abraham formula (Vol. I, pp. 167, 170, see particularly XQ592, p. 170).

we here desire to comment upon several erroneous general assertions of the Court on which its ultimate conclusion was based.

1. For example, the Court of Appeals stated (Vol. II, p. 1168, fol. 1402):

> "No successful use of any other directional wireless is referred to until antennas made under the patents here to be considered were built."

Undoubtedly the Court's opinion of validity for the patent was predicated upon this erroneous belief. The entire want of factual or record support for this statement is found in the fact that directional antennas were concededly old in the art. The first Carter patent in suit, applied for in 1923, was for such antenna, and as respondent's expert Hogan admitted (Vol. I, p. 164), directional antennas were old even at that time. Of course, directional transmission of long waves preceded this work by many years.

Moreover, it should be noted that the express purpose of Abraham's scientific investigation was to determine the direction of radiation.

Finally, with reference to the Court's implication in the foregoing quoted portion of its opinion that the Carter patent discloses the first "successful" directive antenna, we again point out that the patent, on its face, as experts on both sides agree, is expressly directed to antennas which radiate *in the plane of the wires.* The Court of Appeals itself states (Vol. II, p. 1172) that long distance, short wave transmission is *not,* in fact, commercially carried on *in the plane of the wires.* In effect, therefore, the Court of Appeals in one breath has sustained as valid a patent for something which it states in the next breath is of no utility.

We are not here dealing with an illiterate or unskilled inventor. To the contrary, we are dealing with a patentee of recognized standing in the radio art, who, aided by highly skilled patent solicitors and counsel, in spite of the initial position of the Patent Office Examiner, after extensive argument and numerous oral interviews, secured a patent on the theory that:—although short wave directive antennas were *old*, it was *new* to produce an extreme concentration of the radiation *within the plane of the wires and along the axis of the V*, by selecting the *precise* angle for each *exact* length of antenna wire *if* it was of an integral number of half wave lengths. For that, and nothing else, the patent issued. Now that it has been demonstrated that even if such an arrangement were novel it would be utterly useless, the Court of Appeals has broadened the patent and has included within it all *practical* antennas to which the patent did not and could not apply, and has *excluded* from the patent the only antennas to which the patent on its face is directed, viz: one in which radiation is confined to the plane of the wires.

2 The Court of Appeals further said (Vol. II, p. 1169):

> "Although the theory of operation of a single wire had been previously developed prior to Lindenblad and Carter, no one had found how the theory could be utilized in the solution of the problem of constructing a highly directive antenna."

Here, again, the error of the Court of Appeals is so palpable as to require but little comment beyond what has been said above. There is not one word of evidence to this effect in the record in the case, and the prior Carter patent, applied for in 1923, as well as both of the prior Lindenblad patents, constitute complete, unarguable refutation to the Court's statement.

Conclusion.

The Carter patent, in the light of the evidence in this case, is a wholly worthless thing, used by no one, not even by respondent who here asserts it. It is directed to a theory which *is* not, and according to even the Court of Appeals below, *could* not be used practically. It is neither valid nor infringed by petitioner's antennas. The Trial Judge was correct in so holding, and his findings were amply supported by the evidence. The Court of Appeals committed error, under these circumstances, in reversing the findings of the Trial Judge and in holding the Carter patent to be either valid or infringed.

In consequence, the decision of the Court of Appeals should be reversed.

Respectfully submitted,

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APPENDIX.

SEC. 4888. Before any inventor or discoverer shall receive a patent for his invention or discovery, he shall make application therefor, in writing, to the Commissioner of Patents, and shall file in the Patent Office a written description of the same, and of the manner and process of making, constructing, compounding, and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art or science to which it appertains, or with which it is most nearly connected, to make, construct, compound, and use the same; and in case of a machine, he shall explain the principle thereof, and the best mode in which he has contemplated applying that principle, so as to distinguish it from other inventions; and he shall particularly point out and distinctly claim the part, improvement, or combination which he claims as his invention or discovery. The specification and claim shall be signed by the inventor.

SEC. 4892. The applicant shall make oath that he does verily believe himself to be the original and first inventor or discoverer of the art, machine, manufacture, composition, or improvement for which he solicits a patent; that he does not know and does not believe that the same was ever before known or used; and shall state of what country he is a citizen. Such oath may be made before any person within the United States authorized by law to administer oaths, or, when the applicant resides in a foreign country, before any minister, charge d'affaires, consul, or commercial agent holding commission under the Government of the United States, or before any notary public judge, or magistrate having an official seal and authorized to administer oaths in the foreign country in which the applicant may be, whose authority shall be proved by certificate of a diplomatic or consular officer of the United States.

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IN THE

Supreme Court of the United States

OCTOBER TERM, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,

Petitioner,

vs.

RADIO CORPORATION OF AMERICA,

Respondent.

BRIEF FOR RESPONDENT

JO. BAILY BROWN,
ABEL E. BLACKMAR, JR.,
HARRY TUNICK,
Counsel for Respondent.

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IN THE

Supreme Court of the United States

OCTOBER TERM, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,

Petitioner,

vs.

RADIO CORPORATION OF AMERICA,

Respondent.

BRIEF FOR RESPONDENT

The sole issue before this Court is the correctness of the decision of the Circuit Court of Appeals for the Second Circuit (MANTON, LEARNED HAND, and SWAN, *JJ.*) holding valid and infringed claims 15 and 16 of Carter patent No. 1,974,387, granted to respondent September 18, 1934, for an antenna structure for use in radio communication. There has been no other litigation on the patent, and no new or disputed questions of law are raised. The trial court (CAMPBELL, *J.*) construed the patent to be so limited by its disclosure as not to be infringed; the appellate court construed the patent differently and found infringement.

Opinions of the Courts Below

The opinion of the District Court for the Eastern District of New York is reported in 16 Fed. Supp. 610 (II, 1133).[1] In this opinion and in the testimony, the Carter

[1]References to the record herein are by volume and page. Thus "II, 1133" means "Volume II of the record, page 1133".

patent that is now before this Court is referred to as the "third Carter patent".

The opinion of the Court of Appeals is found in 96 Fed. (2d) 587 (II, 1167).

Jurisdiction

Jurisdiction of the Court is not questioned by respondent.

Reply to Petitioner's "Statement of the Case"

Petitioner's "Statement of the Case" (pp. 3-6 of its brief) deals to a considerable extent with matters outside the record, and having no bearing on the issues. Nevertheless, as petitioner seems to think these matters of importance, we make the following comments on petitioner's statement, numbering our paragraphs to correspond to those of petitioner.

1. There is nothing in the record to support petitioner's statement that "petitioner, and its associated companies, constitute the only competition to the world-wide public radio telegraph service operations of respondent and its subsidiary". Respondent denies this statement.

2. There is no pleading or evidence in this record referring directly or indirectly to what petitioner calls "the radio patent pool". The invention set forth in the patent in suit was a product of experimental research conducted by respondent's engineers. The patent is and always has been owned by the plaintiff-respondent.

3. The statements advanced by petitioner in paragraph 3 of its "Statement of the Case", referring to respondent's relations with third parties, are entirely foreign to the pleadings and evidence and are merely petitioner's conclu-

sions, misleading, incomplete, and wholly immaterial to the issues of this case.

4. The present action is an effort of respondent to enforce a valid patent against a direct infringer. That such enforcement may affect the operations of a competitor is a normal consequence of enforcing any patent. Petitioner was engaged in its "world-wide" radio activities before it commenced the infringement complained of, and there is nothing (except petitioner's argument in its petition for certiorari) to indicate that it will be eliminated from such communication if it has to discontinue this infringement.

5. Petitioner's assertion that respondent "completely altered the statement and claim" of the pending Carter application for the patent in suit to include petitioner's antenna structures after receiving particulars of petitioner's structure and operation is untrue. The contrary is fully shown at pages 37-41, below.

7. The trial court's findings that petitioner's antennas differed "radically" from those described and claimed in the patent here in suit, and that the patent was improperly broadened by amendment, were *conclusions* based upon that court's *interpretation* of the patent and the application therefor as originally filed. *Upon the same documentary evidence*, the Court of Appeals reached different interpretations and conclusions. This Court will have to base its decision upon the same *documents*, and will find *no conflicting fact testimony whatever* bearing upon the conclusions referred to.

8. Of course, the stipulation (II, 1158) that the opinion of the trial court be accepted as its findings of fact

and conclusions of law involved no concession on respondent's part either as to the correctness or completeness of the findings and conclusions. The stipulation was entered into merely for *petitioner's* convenience and at its request so that it would not have to comply with the trial court's request (II, 1157) that proposed findings of fact and conclusions of law be submitted "in accordance with" the opinion.

10. The Court of Appeals did not reverse *any* "essential finding of fact" made by the trial court on conflicting evidence. It merely reached a different *interpretation* of the disclosure of the Carter patent and of the application therefor as originally filed, about which there was no conflict of testimony, and therefore reversed the *conclusions* of the trial court based upon different *interpretations*.

The Subject-Matter Involved

While we assume that, in a case like this, coming to this Court with a unanimous decision of the Court of Appeals below, and no conflicting appellate decisions, the burden is heavily on petitioner to establish reversible error, and that it would probably be sufficient if we should merely answer the points argued by petitioner, nevertheless we feel that, in any case involving the validity and infringement of a patent, the Court should have before it a more complete statement of the subject-matter of the patent, and particularly its relation to the prior and present art, than has been given in petitioner's brief.

As was said by the then Chief Justice of this Court in *Eibel Process Co.* v. *Minnesota, etc., Paper Co.*, 261 U. S. 45, at page 63:

> "In administering the patent law the court first looks into the art to find what the real merit of the al-

leged discovery or invention is and whether it has advanced the art substantially. If it has done so, then the court is liberal in its construction of the patent to secure to the inventor the reward he deserves."

Directional Signaling and Radio Beams

Directive radio transmission is of great commercial importance in "point-to-point" communication,—*i. e.*, where messages are to be exchanged between two or more fixed stations, such, for example, as New York and London. The antenna of a radio *broadcasting* station is designed to send out radio signals equally in every direction (I, 76-77), since it is desired that all of the surrounding public hear the broadcast. But in "point-to-point" radio communication, involving messages for a single receiver, it is highly desirable to concentrate the radiation into a "beam", as it is called, projecting the signal-carrying energy principally in the direction of the desired receiving station, because energy radiated in other directions is not only lost, but tends to disturb and interfere with communication between other stations.

One may visualize the difference between a non-directive broadcasting and a directive communication antenna by comparing their distribution of signal-carrying energy with distribution of light from a street lamp, adapted to illuminate everything around it, and from a searchlight, or automobile headlight, adapted to concentrate most of the light into a beam extending in one general direction only.

Directional signaling is fully discussed by respondent's expert Hogan at I, 76-78 and 80-83, and is well explained in the opinion of the Court of Appeals in this case at II, 1167-1168.

Prior Commercial Forms of Directive Antennas

The problem of directive wireless signaling was one of the oldest in the art.[2] The patents and publications cited by petitioner show that inventors and scientists of note have worked on this particular problem from the earliest days of wireless on down to the present. With the coming into general use of short radio waves for long distance communication about 1923, there was increased activity in such research and active world-wide study of the problem of directive antennas for point-to-point communication. There is no dispute about these points. The activity here and abroad is recited at some length in the historical testimony of respondent's witness Hansell at I, 32-48.

(1) *Early Research on Short-Wave Directional Antennas:*

Directivity is more easily secured where radio communication is carried on by comparatively short waves, *e. g.*, less than 100 meters in length. In the year 1923, when the advantages of the use of such short waves for long distance communication were becoming more apparent to the art, respondent's engineers began a research into the possibilities of directive short wave antennas. This is summarized by Hansell, beginning at I, 32. For about a year, experimental work with such antennas was carried on by respondent's engineers; the work was then taken over by the General Electric Company, where it was carried on for two years or more under such well known radio engineers as Alexanderson, Rice, Kellogg, and Baker (I, 35). Many types of directive antenna were built and tried out; but "substantially no commercial use" appears ever to have been made of any of the antennas thus developed

[2]See, for example, the Brown British patent of 1899 (Defendant's Exhibit AA, II, 839).

(I, 34-35). This experimental work was discontinued in 1926, largely because of the great success which the British Marconi Company realized in that year with its "beam system" directive antenna, working between Canada and England. In 1926 and 1927, respondent purchased two of the Marconi beam antennas, installing one of them at Rocky Point, New York, for transmitting signals to England (I, 35-36) and the other at Riverhead, New York, for reception of signals.

(2) *The Marconi Beam and Telephone Company Antennas:*

The Marconi beam antenna is made up of a complex network, or curtain, composed of sixty-four radiating wires, each made up in a considerable number of sections and suspended vertically from a system of structural steel towers 300 feet high, with cross arms 75 feet long at their tops.[3] In practice it was found very difficult to adjust this antenna and to keep it in adjustment. Wind and ice frequently stripped off the wires; maintenance was very expensive. The initial cost of these Marconi beam antennas which were erected at Rocky Point was between $100,000 and $175,000 each. The antennas were highly directive, and very efficient for concentrating the radiated energy in the direction for which it was intended. (See Hansell's testimony I, 36-39, 44-45.) Here again there is no denial or conflict of testimony.

Because of the difficulty and expense of maintenance, and the high initial and repair costs of the Marconi beam antenna, respondent's engineers again attacked the problem of producing a better form of directive short-wave antenna. This work was carried out by a group of radio engineers working for respondent at Rocky Point, New

[3]See II, 532-534, for details and appearance of the Marconi antenna.

York, under the direction of the witness Hansell. One of these engineers was Lindenblad, who will be referred to later; another was Carter, the patentee of the patent here involved.

Meanwhile,[4] the American Telephone and Telegraph Company was also working intensively on development of short-wave directive antennas. After much research, that company erected, in 1929, its Lawrenceville, New Jersey, station for transatlantic communication. The antenna employed was of the suspended network type, involving high structural steel towers and great expense. (I, 47-48; see also Bruce, I, 377.) Illustrations of that antenna are in the record at II, 609-611, 618-620.

(3) *The Results of Respondent's Research:*

As a result of its research work, respondent's engineers between 1927 and 1930 developed and built four types of directive antennas, referred to in the record respectively as models A, B, C, and D. The patent here in suit discloses and covers model D, the last of this series of developments.

The model A antenna, like the Marconi beam, employed a network of short radiating wires vertically suspended in a curtain-like arrangement.[5] The model A was cheaper than the Marconi antenna, costing about $80,000 to erect. However, it was considerably less directive than the Marconi antenna, and it had the same objections, in that it was hard to adjust and keep adjusted, and the network of wires was frequently injured by wind or ice. Consequently,

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[4]Meanwhile also, in England, Germany and France, independent research developed other types of directive antennas. These are described in Hansell's testimony (I, 46-47). See the illustration of one of the actual antennas at II, 608.

[5]Illustrations and diagrams of this antenna are in the record at II, 535, 536, 555.

maintenance costs were high. Nevertheless, thirty-eight model A antennas were built and put into service by respondent. (I, 39-41, 45.)

Respondent's engineers next tried out a type of antenna that was called an "expanding wire antenna" which comprised an expanding extension of a two-wire transmission line, the wires starting close together at one end and progressively increasing in spacing to the other end. This was the antenna of Figure 1 of the Lindenblad patent No. 1,927,522 (II, 486). No commercial model resulted although, in several instances, the experimental antennas were used to handle commercial traffic. This diverging wire antenna was not as directive as the model A. (I, 41-42.)

Models B and C, which were the next development, were of quite a different type. Each of these models consisted of one or more pairs of long, *parallel,* horizontally supported wires. Units of these types cost, respectively, $30,000 and $48,000 per antenna. These models B and C were more directive than model A, but still were less directive than the Marconi beam antenna. However, they were commercially successful, and upwards of thirty of these two types were placed in commercial service by respondent or its subsidiary. (I, 41-43, 45.) For a while, they looked like the final solution of the short-wave directive antenna problem from a practical point of view.

But meanwhile, Carter was working on another antenna, the model D, which when tried out was found to be superior in economy of erection and maintenance to any of the directive antennas theretofore used. That is the antenna of the patent in suit. By suitably combining the V units as Carter designed them, an antenna is obtained which gives, at a cost of about $5,000, a signal concentration forty times that of a standard comparison unit and equal to that

of a Marconi beam antenna, which cost between $100,000 and $175,000. (I, 45.)

Success of the Carter Model D Antenna That is Covered by the Patent in Suit

Respondent's Exhibit 47 (II, 713) is a letter from Hansell, who was in charge of this directive antenna work, dated May 7, 1930, transmitting Carter's "report on the results of tests recently made on a new type of directive transmitting antenna which he devised." The report itself is dated May 6, 1930, and is Respondent's Exhibit 44 (II, 699-708). Respondent's Exhibit 43 contains a complete description of the new antenna, dated January 4, 1930, and signed by Carter (II, 654-661). The most casual inspection of these exhibits shows that the antenna referred to therein is the antenna of the Carter patent in suit. Indeed, the drawings of the patent appear to have been taken from the Carter memorandum of January 4. (See pages 1 to 5 of the memorandum.)

Hansell's letter, Exhibit 47, after calling attention to the fact that this new type of antenna seemed to be a decided improvement (over models B and C) due to its improved directivity and greater simplicity and economy of structure, suggested

> "that consideration be given to substituting the new antenna for the original harmonic types in the present construction programs for Rocky Point, New Brunswick, Bolinas, Kahuku (Telephone) and other places",

and estimates a total saving to respondent, "if all the new transmitters now scheduled were equipped" with this new model D antenna, of at least $3,500,000.

The first of these model D antennas which went into commercial service was placed in Bolinas, California, in

1930. At the time of the trial, forty such antennas had been erected and placed in operation by respondent or its subsidiary. (I, 44.)

The Published Description of Carter's Antenna

A complete description of the structure, mode of erection, and operation of, and an elaborate mathematical analysis of the radiation from, the model D antenna were given in a paper read before the Institute of Radio Engineers in June of 1931 and published in its Proceedings in October, 1931. This paper is Plaintiff's Exhibit 20, and it is reproduced in full in the record at II, 538-607. *There can be no question but that this paper "contains sufficient information as to structure, arrangement, and adjustments to enable a radio engineer to construct and operate the antennas there described"* (I, 44). There is no dispute on this point in the testimony.

During the year following the publication of Carter's Institute of Radio Engineers paper, petitioner (which had previously carried on its "world-wide" communications with other types of antennas) erected the first of the eleven accused antennas at its Sayville, New York, station (I, 29). As appears from a mere inspection of the stipulated diagrams,[6] and as will be shown in detail below, these antenna structures of petitioner are *substantially identical with the model D antenna invented by Carter,* and described in the publication above referred to, previously erected and put into commercial service by respondent, and subsequently patented.

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[6]II, 510, 514, 518, 522, 525, 529.

The Carter Patent in Suit No. 1,974,387

The fundamental unit of the antenna of the Carter patent in suit, and of petitioner's antennas, is simple and easy to visualize. It involves structurally merely two long,[7] straight wires arranged in V form, having the wire length, wave length, and angle between the wires co-ordinated as directed in the patent. This simple structure will readily appear from an inspection of the insert opposite this page, comprising reproductions of Figure 4 of the Carter patent and of the stipulated diagram of petitioner's antenna No. 2 (original).

Carter's specification begins with the statement (II, 499) that it is known, that is to say that it is prior art so far as he is concerned, that when a single straight wire (antenna) is excited by a radio current so as to produce standing waves[8] on the wire, the wire being longer than the radio wave, the predominant radiation from that wire will go out into space in the very curious way indicated in Figure 1a of the patent. In this figure, the horizontal line 2 is the wire; the radiation goes out principally in the directions marked Y, Y, Y, Y, or rather not merely in those four

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[7]The term "long", as used herein and in the record, in connection with wires, means wires which are long *in relation to* the wave length used. Thus, a 600-foot wire is "short" if used with a wave length of 1,000 feet but "long" if used with a wave length of 100 feet.

[8]Radio engineers speak of two kinds of waves on an antenna wire: standing waves and traveling waves. If we take an extremely long wire and introduce radio waves, or, more properly, oscillating current of radio frequency, into one end of it, waves will travel down the wire, radiating their energy into space as they travel, until finally their energy is exhausted before they reach the end of the wire. These are called "traveling waves" (I, 95-96 and 111). If the antenna is somewhat shorter, the entire energy of the waves will not have been radiated when they reach the end of the wire and the waves will, when they reach the end, be reflected back along the wire, until finally a steady condition of things results, in which "standing waves" exist along the length of the radiating wire (I, 96-97).

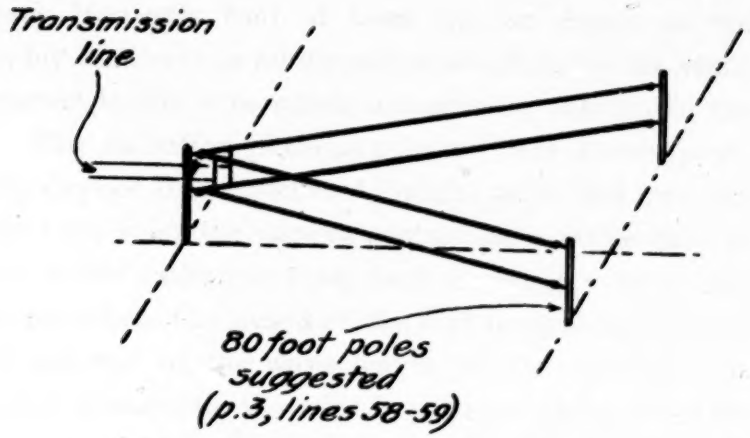
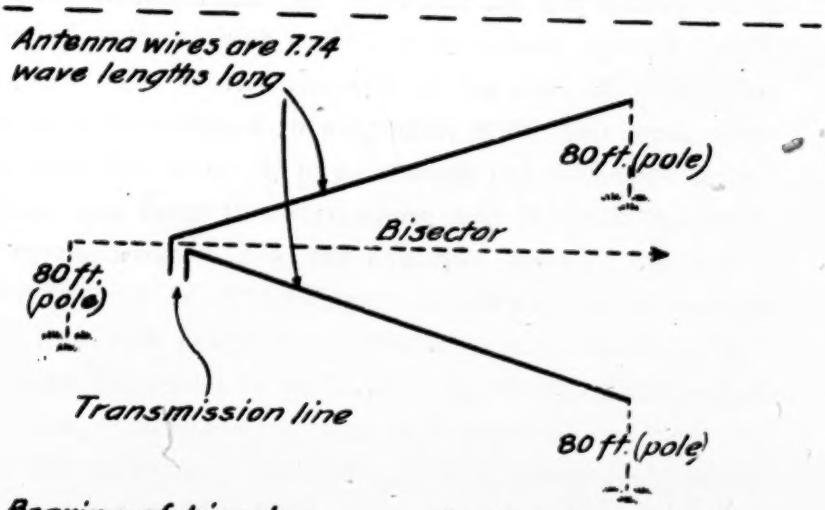


Fig. 4 of Carter Patent (single V)
(The extra V is an optional arrangement; p.3, lines 24-27)



Bearing of bisector is N. 49.75° E.; bearing of Vienna is N. 49.74° E. (II, 530)

Angle between bisector and each antenna wire is 17.5°; angle recommended by Carter is 17.8° for wires 7.74 wave lengths long (I, 139)

Petitioner's Antenna No. 2 (original)
Diagram annexed to plaintiff's Exhibit 10
(II, 522)

directions (for only four of them can be shown on the paper), but similarly in all directions which make the angle with respect to the wire which is marked α (alpha) in the figure. This radiation phenomenon had been known since the early days of the art, when Abraham published (in 1898 and 1901) his scientific papers containing a mathematical analysis of the radiation from such a single wire in the special case where the length of the wire is an *integral* multiple of one-half of the wave length of the current.[9] In Abraham's discussion, the wire is assumed to be "in free space", *i. e.*, so far removed from all other conductors (such as the earth) that the radiation travels uninterruptedly to infinite distances in the original directions.

The actual three-dimensional distribution of the predominant radiation may be visualized by comparison with a pair of rather thick-walled megaphones placed small end to small end around the wire at the point at which the radiation is considered to originate, with their axes coinciding with the wire. It is as though the principal radiation went out from the wire along and through the thick walls of the megaphones; for example, between the heavy line 6 in Figure 1a of the Carter patent and the unmarked dotted line just below it. Naturally, any receiving station which happened to lie in any one of the directions Y would receive more energy than stations in other directions.

But there are many such directions Y, actually an infinite number: on each side of the wire, above it, below it, in fact all the way around it. Therefore a large part of the radiated signal energy is wasted by such an arrangement, because much of the energy goes out in directions that do not include receiving stations with which it is desired to communicate.

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[9]Petitioner's Exhibit V, II, 761-784.

The first of the antennas of the Carter patent, the one shown in Figure 2b, reduces this waste enormously. It is a very simple structure, consisting of two wires, A and B, which in practice may be strung on telegraph poles 80 feet high (patent, p. 3, line 58, II, 501) and are connected by the wires 10 with the source of energy at the radio station. The two wires A and B spread out from each other in such a way that the angle between them is twice the angle *alpha*, which is the angle between the wire 2 of Figure 1a and any one of the lines Y. The two wires A and B are connected respectively to the two terminals of the radio supply circuit, a simple matter that results in the condition which is referred to in the record by the rather occult term "phase opposition" (I, 113-114).[10]

The result of Carter's arrangement is a very powerful signal transmission in both directions along the line X-X of Figure 2b. As Kelley, petitioner's expert witness, puts it (I, 216-217):

> "The third Carter patent[11] arranges the wires of the V in such a manner that these principal lobes of radiation, of which I just spoke, on the inside, so to speak, of one wire, with the principal lobe in the inside of the other wire, so it all will come together when the angle between the principal lobe of radiation and the wire is equal to the angle to the bisector of the two wires, in other words, that *these lobes will now*

[10]Connecting the wires in "phase opposition" merely means that the wires are connected to the opposite poles of the generator. The result is that when a given point on one wire has, at a given instant, a positive electric charge, the corresponding point on the other wire has a negative charge. It is admitted that petitioner's antenna wires are excited "in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length",—as described in Carter's claim 15.

[11]The "third Carter patent" is the one that is before this Court. The first and second Carter patents related to another subject,—impedance matching.

combine exactly in the plane of the wire and along the direction of the bisector." [12]

But curiously enough, this is not the only result. In a manner which is too complex for easy explanation, the other portions of the "cones" or "tubes" of radiation and also the smaller cones, appearing in Figure 1b as "ears", or "lobes" as they are called, substantially disappear, canceling each other out. Much of the energy that went into them in the case of the single wire is, in the V arrangement of the two wires diverging at substantially the angle two-*alpha*, radiated as a part of the beam that has its axis on the bisector of the angle of the V antenna. This affords a maximum concentration of radio energy along the line X-X.[13]

Figures 2a and 2c have to do with details of the supply of energy, tuning, etc. Figure 3 is a plot of the distribution of energy radiating from the antenna shown in Figure 2b, showing a very strong preference in the direction X-X, front and rear,—a strong two-way ("bidirectional") beam.

Figure 4 introduces another feature, one which is not used by petitioner, consisting of the additional wires A′ and B′ mounted below the main antenna wires and parallel with them.

A further improvement appears in Figure 5. We have said, and it appears from Figure 3, that the antenna of Figure 2b radiates energy in both of the directions X-X; that is to say, both forward and backward. It is usually desirable that the radiation should be concentrated in one direction,—*i. e.*, that the antenna should be made "unidirectional". This is accomplished by the use of an addi-

[12]Emphasis herein is ours unless otherwise stated.

[13]See I, 122, 455; also, compare Figures 1b and 3 of the Carter patent.

tional pair of wires, a, b, etc., mounted behind the main wires A, B, etc., the additional wires being located "an odd number of quarter wave lengths" behind the main wires, and being so fed with current that the standing waves of current which they carry have a certain definite phase relation with the standing waves in the main antenna wires A, B, as set forth in the last column of page 3 of the patent.

The effect of all this is to reverse the radiation which is shown in Figure 3 as going out to the left along the line X-X, to turn it around, and to superimpose it on the radiation which is going out to the right. The distribution of radiated wave energy would then appear, in plan view,—*i. e.*, to one looking down from above,—as it appears in the plot, Figure 6.[14]

Figure 7 is a corresponding plot of the wave energy in the "vertical plane"; that is to say, it shows how much of the energy goes out horizontally as compared to directions at angles to the horizontal. This vertical distribution, we remark in passing, is, at a distance from the antenna, somewhat altered by the well-known earth reflection, or "ground effect", referred to in the legend on Figure 7. That will be discussed in detail later.

There is nothing mysterious in these plots; they graphically represent the "beams" of radiated energy from an antenna *per se*,—*i. e.*, when ground effect is neglected. They also indicate the energy quantitatively, for if a line such as the line marked 10° be drawn on the plot, as it is drawn on Figure 7, the distance from the origin of the line to the point where it crosses the cigar-shaped boundary

[14]Of course, Figure 6 is not drawn to the same scale as Figure 3, for the use of a double V, to secure unidirective action, approximately doubles the radiation in the desired direction as compared to a single V (I, 125).

curve of energy distribution represents the relative amount of energy radiated in that particular direction. Thus it appears from Figure 7 that substantially no energy is radiated at an angle of 20° upward, but that a good deal of energy is radiated at an angle of 10° upward, whereas it appears from Figure 6 that very little energy is radiated horizontally at 10° to the left of the preferred direction, that is, the direction of the line pointing to the receiving station, and that no substantial amount of energy is radiated more than 5° to the right or to the left of that line (I, 79-80).

The remaining figures of the patent, except Figure 12, relate to refinements which are not here involved; we see no need to discuss them.

Figure 12 of the patent is a graph by means of which, having chosen the length of the radiating wires (to suit the amount of ground available or otherwise) and the wave length to be used, one can readily determine the proper angle between the wires and set up a V antenna to get maximum concentration of radiation along the bisector of the angle of the V. From this it appears that the angle gets smaller as the length of the wire in terms of wave length increases, being about 72° at two wave lengths, 50° at four wave lengths, 42° at six wave lengths, 36° at eight wave lengths, etc.

The Carter patent describes single-V and double-V, long wire antennas, carrying standing waves, and teaches, for all finite lengths of wire, the optimum relation of the angle between the wires, the lengths of wires, and the wave length employed, for obtaining maximum radiation along the bisector of the angle between the wires.

The two claims in suit define Carter's antenna structure and set forth the optimum relation (which results in maxi-

mum radiation along the bisector of the angle between two antenna wires arranged in V-shape and fed in phase opposition) of the *wire length, wave length,* and *angle between wires.* This relation is defined by a mathematical formula involving the three variable quantities. Knowing any two, the other is determined by the formula. It holds good for any finite wire length.

Petitioner's V Antennas

In considering what had been *used* in the prior art for directional antennas, and by way of showing that petitioner did not follow the prior art, and why not, the testimony of its own chief engineer, Mr. Pratt, is most enlightening. *Mr. Pratt was the engineer entirely responsible for the design and construction of petitioner's V antennas* (I, 204). Previously, he had been a radio engineer for the Marconi Wireless Telegraph Company of America and had superintended construction of some of its antennas (I, 200). Then he was an expert radio aide in the Navy Department. As such he "was in charge of engineering and maintenance and design of all of the high power radio stations operated by the Navy Department." After that he was in charge of "engineering work for the Federal Telegraph Company and built a system for them" (I, 200). That company "operated a commercial radio station system, which extended up and down the Pacific Coast, connecting the various cities there by radio telegraph for commercial service." Then he built "a system of communication for the Western Air Express, between Utah and California." After that he was "in charge of development of radio aids for air navigation under the Commerce Department, Bureau of Standards," until he became chief engineer of petitioner in 1928. He testified (I, 201):

"During this time, particularly while I was in charge of the radio work for the United States Navy, I had many occasions to inspect radio transmitting and receiving stations. *I examined several hundred radio transmitters during this time.*"

Now, with that background of continuous experience in the practical art from 1914 on, note that Mr. Pratt, on cross-examination, said (I, 204):

"I spoke of having seen a great many transmitting stations. *As physical structures, the first ones that I saw that had an antenna in the form of a V with long straight wires, long in terms of wave lengths, and excited in phase opposition, were those which we erected at Sayville.*"

And just before this, on the same page, Mr. Pratt said:

"*The V antennas that I put up at Sayville were the most effective that I knew of at that time,* for the amount of money that I wished to spend on them • • •. To put up one of our double V antennas at Sayville it cost perhaps two to three thousand dollars • • • that is the cost of labor and material."

Mr. Pratt makes no claim to have followed the prior art, or to have *originated* anything, in constructing petitioner's antennas.

The V antennas used by petitioner are described in the stipulated descriptions (Pltf.'s Exhs. 7 to 12, II, 507-529), diagrams being given in each instance. Various dimensional data are set forth in Plaintiff's Exhibit 13 (II, 530-531).

In general, two types of V antennas have been used by petitioner,—single V's and double V's, the former being

bidirective and the latter unidirective. We will describe one antenna of each type.

We have reproduced above (opposite p. 12) the stipulated diagram of *petitioner's single-V antenna No. 2 (original)*. The antenna itself was composed of two long, straight wires, CA and DB, arranged in the form of a V. The other elements shown in the diagram (II, 522) are the "transmitter" or source of electrical oscillations, the transmission line, and the impedance matching circuit. These elements are of no interest now except that they show that the two wires of the antenna were fed in "phase opposition" (see footnote 10, p. 14, above) so that the wires had standing waves of opposite instantaneous polarity thereon (elements of Carter's claim 15 which are admittedly present in all of petitioner's antennas). The angle between each wire of petitioner's antenna No. 2 and the bisector of the angle between them was 17.5°; Carter's formula and curve call for an angle of approximately 17.8° for wires of this length (I, 139). The compass bearing of the bisector of this antenna was N. 49.75° E. (II, 530); in the stipulated data, this is referred to as the "Directivity" of the antenna. This particular antenna was used for communication with, among other places, Vienna, the direction of which is N. 49.74° E. from Sayville, which is substantially that of the bisector.

Petitioner's antenna No. 1 is representative of its *double-V* antennas. The stipulated diagram of that antenna appears in the record at II, 518. There are two V's, one composed of the wires CA and DB, and the other of the wires C′A′ and D′B′,—C′A′ being parallel to CA and D′B′ to DB. By separating the two V's an odd number of quarter wave lengths (three quarters in this case) and feeding the two V's with electrical currents in phase quadrature (90° out of phase), unidirective action is secured,

as explained in the Carter patent; thus the radiation in the direction along the bisector from the apices of the V's toward the open end of the antenna is canceled and the radiation in the opposite direction along the bisector is increased (nearly doubled). The bearing of the bisector ("directivity" of the antenna system) is N. 281.95° E. and the antenna is used for communication with San Francisco, the bearing of which is N. 281.28° E. from Sayville. The angle between the bisector and each wire is 20°,—the Carter formula and curve calling for an angle of about 19.93° for wires of this length (I, 162).

Petitioner's map of its Sayville station[15] shows the lay-out of its various V (and other) antennas. The wire lengths and angles employed in each of petitioner's V antennas are given in the Appendix on the inside of the back cover of this brief.

SUMMARY OF ARGUMENT

For the convenience of the Court, our reply to the defenses raised follows the order of petitioner's argument. It may be summarized as follows:

Point I. The Carter patent is infringed, petitioner's antennas being constructed in accordance with the description in the patent and being covered by claims 15 and 16, here in suit.

Petitioner's contentions that it does not infringe are unsound for the following reasons:

(1) The Carter patent is not limited to antennas which radiate only in the plane of the wires;

(2) Petitioner's antennas all radiate predominantly in the direction of the bisector of the angle of the V;

[15]Plaintiff's Exhibit 23A, II, 622.

(3) The fact that most of petitioner's antennas do not use wires that are an integral number of half wave lengths long does not avoid infringement; and

(4) Petitioner's antennas use the angles specified in the Carter patent.

Point II. The Court of Appeals did not reverse any findings of fact which were made by the District Court on conflicting evidence.

Point III. There was no expansion of the subject-matter of the application for the Carter patent, improper or otherwise.

Point IV. Under the circumstances, no supplemental oath was necessary.

Point V. The Carter patent is valid over the prior art,—in particular, over

(1) The Abraham articles of 1898 and 1901;
(2) The Bethenod French patent No. 596,737;
(3) The Bethenod French patent No. 625,293;
(4) The Levy French patents;
(5) The Lindenblad V antenna patent; and
(6) The prior work of Bruce.

Point VI. Under this heading, we reply to certain specific matters in petitioner's brief. We consider it unnecessary to summarize these points; they are covered by the numbered sub-headings which are also included in the index.

ARGUMENT

POINT I

The Carter Patent is Infringed.

The Carter application as filed, the Institute of Radio Engineers paper, and the Carter patent each described a directive antenna, told how to construct it, suggested (II, 1039; II, 501, lines 58-59; and see II, 605) that it be set up on poles 80 feet high, illustrated it as strung from such poles, and described and illustrated in what direction the antenna would be effective. Petitioner constructed its V antennas, utilizing the co-ordination of wire length, wave length, and angle specified by Carter, set them up on poles 80 feet high (II, 530), and secured antennas that are effective exactly as those that Carter described.[16]

As petitioner says (brief, p. 10), "the present litigation has to do solely with antenna *structure.*" (The emphasis is petitioner's.) Structurally, petitioner's antennas are identical with Carter's and they secure the same results that Carter described,—concentration of radiation in the direction of a distant receiving antenna,[17] simplicity, and

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[16]Direct proof of this is available as to petitioner's antenna No. 1. The directive characteristic of this antenna was measured in the field by Hansell and its directive pattern is given in Plaintiff's Exhibit 24, II, 623. It also follows directly from the testimony of petitioner's Chief Engineer, Pratt, who testified (I, 203):

> "They [the signals] were propagated in the vertical plane containing the bisector of the angle of the wires."

[17]Pratt testified (I, 203-204):

> "I spoke yesterday about changing the direction of some of the antennas at Sayville. By 'changing the directions' I meant the destination to which the signals were intended to go was changed from one place to another. I brought about that change of direction by moving the wires so that they would lie in a different place than they did before. In bringing about this change of direction, the bisector of the angle of the V was changed, of course, when the wires were changed. That was changed from the original destination to the new desired destination, *so that the bisector of angle which formerly bore on one particular point was changed so that the bisector of the angle of the V bore on the new destination.*"

efficiency. They were used to attain those results as well as the highly important result of economy in construction costs. Thus, petitioner's Chief Engineer, Pratt, testified that cost is usually the first consideration (I, 202) and that it cost $2,000 to $3,000 to put up one of petitioner's double-V antennas (I, 204). Equally directive prior structures would have cost upwards of $100,000. (See pp. 7, 9-10, above.)

Claim 15 of the Carter patent reads as follows:

> "An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)-0.513$ degrees, l being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length."

The claim (and the same is true of claim 16, the other claim that is before this Court) describes only structure and says nothing about radiation in the plane of the wires or along the bisector.[17a]

All of petitioner's V antenna wires are "relatively long", being from 4 to 8.14 wave lengths long. The angles used by petitioner in nine of its eleven V antennas are almost exactly the angles determined by the formula set forth in the claim; as to the other two antennas, the angles are sufficiently close to secure predominant radiation in the desired direction, as taught by Carter. (See the stipulated descriptions of the antennas, II, 507-531, and the Appendix on the inside of the back cover of this brief.)

The means recited in the claim,

> "for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length",

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[17a] As we shall see later, petitioner's antennas radiate exactly as Carter's antenna radiates.

is admittedly present in petitioner's antennas.

This claim accurately defines all of petitioner's V antennas, both single-V and double-V.

Claim 16 differs from claim 15 primarily in calling for

> "a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors".

This claim also accurately defines all of the petitioner's double-V antennas,—namely, Nos. 1, 4, 5, 6, 7, 8, 9, and 10.

Petitioner's Contentions That It Does Not Infringe the Carter Patent Are Unsound

As we understand petitioner's position, it argues non-infringement on four grounds: (1) that the patent is limited to antennas utilizing the predominant radiation which goes out exactly in the plane of the wires (horizontal plane) to the exclusion of radiation which goes out at small angles above and below that plane; (2) that its antennas do not radiate predominantly in the direction of the bisector; (3) that the patent is limited to antennas the wires of which are an integral number of half waves long; and (4) that the patent is limited to antennas utilizing the exact angle recommended by Carter (not even allowing a variation of as little as 0.02°).[18]

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[18]See the testimony of petitioner's expert, Kelley (I, 309):

> "XQ. 1404. Now, going back to the previous subject, my attention has been called to the fact that you have not said whether *ground effects* and *differences in angle* are the *only* things that might make defendant's antenna operate on a different principle from that taught in the third Carter patent? A. I believe I answered that with a 'yes'.
>
> "XQ. 1405. Those two things are the *only* things? A. *Yes, sir.*"

Note that *petitioner's expert* did not mention the use of wires not an integral number of half waves long as a difference distinguishing petitioner's antennas from the patented structure.

(1) *The Carter patent is not limited to antennas which radiate only in the plane of the wires:*

When an antenna is placed over ground (*e. g.*, on 80-foot poles), the presence of the ground affects the ultimate angle of the predominant radiation in relation to the horizontal plane, *but not its directivity in compass directions* (I, 129). This was known when Carter filed his application and this fact is not denied by petitioner.

The unavoidable effects of the presence of ground are (a) that radiation that leaves the antenna in the exact mathematical plane parallel to the earth (the horizontal plane) is, *at a distance from the antenna,* cancelled by radiation that leaves the antenna at a slight downward angle and is reflected upward from the ground; and (b) that radiation which leaves at a small upward angle is, *at a distance from the antenna,* reinforced by radiation that leaves at a similar downward angle and is reflected from the earth's surface. *The experts are in complete agreement on these points.* (See Hogan, I, 128-129; Kelley, I, 282-283.) These are *inescapable* effects (Kelley, I, 343); they *always* occur when short-wave antennas are placed as both of the parties place them and as they are necessarily placed,—*i. e.*, not far above the surface of the ground. They are collectively called "ground effect".[19] Their joint effect is slightly to elevate or tilt the beam upward, without making any change in its horizontal or compass orientation.

This elevation of the beam, which is only noticeable at a distance from the antenna, does not, as might seem at first glance, destroy the effectiveness of the antenna as a source of signals for a distant receiving sta-

[19]Of course, neither respondent's engineers nor petitioner discovered these ground effects. They have been long known in the art. (See, for instance, Kelley's testimony, I, 252-253, to the effect that the Levy patent of 1925 explained them.)

tion. Long-distance, short-wave transmission, as has long been recognized,[20] is not carried on by means of signals transmitted horizontally along the surface of the earth; the signals that reach a distant receiving antenna are those that have left the transmitting antenna at a small upward angle (possibly 10° above the horizontal) and been deflected back to earth by the so-called "Heaviside layer",—a portion of the upper atmosphere that reflects radio waves due to the fact that it is conductive because of ionization. (See Kelley, I, 209, Q. 295.)

Petitioner's statements (brief, pp. 12-16, 23, etc.) that Carter described his antenna as giving predominant radiation in the plane of the wires can mean no more than that he described the action of his antenna *per se, i. e.*, as though it were located in "free space"—("ground effect neglected", *as Carter himself expressed it* in Figure 7 of his patent). The experts agree that, *neglecting ground effect,* the predominant radiation *is* in the plane of the wires, not only in the case of Carter's antenna but also in the case of petitioner's antennas.[21]

Carter did not think it necessary to analyze or describe in detail the well-known and inevitable effects of ground, and it was not necessary for him to do so (see the cases cited below, at pages 29-31); however, he clearly indicated that he was intentionally omitting such description. It would be as fair to hold a building specification fatally defective because it did not mention the law of gravity, as to treat Carter's disclosure as did the trial court and as petitioner asks that it be treated. And petitioner's argument (brief, p. 24) that it does not infringe because (it says) its an-

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[20]See, for example, Deft.'s Exh. V (II, 789) and Deft.'s Exh. AA (II, 862, 883); see, also, Kelley, I, 251-252.

[21]Carter patent, Fig. 7, II, 494; Hogan, I, 128-129; Kelley, I, 282-283, XQ. 1167; I, 274, XQs. 1090-1; I, 276-277, XQs. 1113-15; Defendant's Exhs. S and T, II, 745, 746; Kelley, I. 275, XQ. 1104.

tennas radiate energy predominantly at a small angle above the plane of the wires, can only mean that it is referring to the radiation that results *at a distance,* due to the inevitable ground effects. Its antennas are exactly the antennas described in Carter's patent and in the paper (Plaintiff's Exhibit 20) published eight months before petitioner's first V antenna was built; in "free space", they would radiate exactly as Carter described (Kelley, I, 274); and over ground, in actual use, the radiation in horizontal or compass directions from petitioner's antennas and that from the antenna described in the patent are identical. As ground effect, in practical use of any fixed antenna, is *inescapable,* the necessary effect of petitioner's argument on this point is that the Carter patent, although describing the *exact structures* that have been adopted and commercially used by respondent's subsidiary and by petitioner, describes an antenna which it is *impossible* to construct (Kelley, I, 274, XQs. 1095-6).

The fact that Carter described the action of his antenna as it would be in "free space",—leaving it to the engineer to determine, if necessary, from knowledge *existing when he filed his application,* what the effects would be of the particular character of ground over which he wished to construct his antenna,—does not limit his patent to antennas located in "free space" and *exclude* antennas located (*in accordance with his recommendations and description*) over the ground (*e. g.,* on 80-foot poles or "about three-quarters of a wave length above ground"—II, 501, lines 54-59).

But even if (as is inconceivable and contrary to the notation on Fig. 7 of the patent) Carter had been ignorant of ground effect, what difference would that make? There was no deficiency in his description of the *structure* of

his antenna. He (like petitioner[22]) was concerned with an antenna which would concentrate the radiation in the direction of a distant receiving station. If one set up an antenna *exactly as described in the Carter patent,* he would not need to know even what the art already knew as to the effect of ground; he would need no information not given in the Carter patent. If he measured the directivity *near the antenna* (as Hansell measured that of petitioner's antenna No. 1[23]), he would obtain a directive pattern like that of Figure 6 of the patent; and the signals received at distant receiving stations would vary in strength according to their direction from the transmitter in accordance with that directive pattern,—the strongest signal being received at stations lying in the direction of the bisector of the angle between the wires.

Also, the distinction between the action of an antenna when ground effect is neglected and normal or "over ground" action is not carried into the claims of the Carter patent. The claims describe antenna *structures* for use wherever and however desired and these structures are used by respondent's subsidiary *and* by petitioner.

That a patentee is not required to write into his specification matters of general knowledge or matters known to those skilled in the art is settled law in this Court. It is equally well settled that if he discloses a practically operative device he need not know the theory of operation, or may be mistaken as to the theory,[24] without prejudice to the validity of his patent.

In *Carnegie Steel Co.* v. *Cambria Iron Co.,* 185 U. S. 403, 437, this Court held:

"The specification of the patent is not addressed to lawyers, or even to the public generally, but to the

[22]See Pratt's testimony quoted in footnote 17, p. 23, above.

[23]See I, 48-50 and Pltf.'s Exh. 24 (II. 623).

[24]There is no mistake in the Carter patent as to theory.

manufacturers of steel, and any description which is sufficient to apprise them in the language of the art of the definite feature of the invention, and to serve as a warning to others of what the patent claims as a monopoly, is sufficiently definite to sustain the patent. *He may assume that what was already known in the art* of manufacturing steel *was known to them,* and, as observed by Mr. Justice BRADLEY, in *Webster Loom Co.* v. *Higgins,* 105 U. S. 580, 586, 26 L. Ed. 1177, 'he may begin at the point where his invention begins, and describe what he has made, that is new, and what it replaces of the old. *That which is common and well known is as if it were written out in the patent and delineated in the drawings.*' "

In *Diamond Rubber Co.* v. *Consolidated Rubber Tire Co.,* 220 U. S. 428, 435-6, this Court said:

"A patentee may be baldly empirical, seeing nothing beyond his experiments and the result; yet if he has added a new and valuable article to the world's utilities, he is entitled to the rank and protection of an inventor. And how can it take from his merit that he may not know all of the forces which he has brought into operation? It is certainly not necessary that he understand or be able to state the scientific principles underlying his invention, and it is immaterial whether he can stand a successful examination as to the speculative ideas involved. [Cases cited.] He must, indeed, make such disclosure and description of his invention that it may be put into practice. In this he must be clear. He must not put forth a puzzle for invention or experiment to solve but *the description is sufficient if those skilled in the art can understand it.* This satisfies the law, which only requires as a condition of its protection that the world be given something new and that the world be taught how to use it. It is no concern of the world whether the principle upon which the new construction acts be obvious or obscure, *so that it inheres in the new construction.*"

As stated by JESSEL, M. R., in *Plimpton* v. *Malcolm*, 3 Ch. Div. 531, at page 568:

> "the specification of a patent is not addressed to people who are ignorant about the subject-matter. It is addressed to people who know something about it."

Of course, in the present case, "ground effect" was well understood by Carter and everybody else skilled in the art and was referred to in the patent by a legend on the *only* figure on which such a reference had any meaning whatever.

The Carter patent must be read in the light of this knowledge of the inescapable effect of ground and, as this Court said in the *Carnegie Steel Co.* case, cited just above, it is as if this knowledge "were written out in the patent".

(2) *Petitioner's antennas all radiate predominantly in the direction of the bisector of the angle of the V:*

Petitioner's second point on the question of infringement (brief, p. 25) is not argued. What petitioner must mean is that, due to ground effect, the radiation from its antennas, which is effective *at a distance,* goes out at an upward angle and hence not on the *mathematical line* of the bisector. Admittedly, however, petitioner's antennas were laid out so that the bisectors of the angles pointed in the direction of the desired receiving station and the radiation goes out from them "in the vertical plane containing the bisector" (Pratt, I, 203),—*i. e.,* in the compass direction in which the bisector points.

(3) *The fact that most of petitioner's antennas do not use wires that are an integral number of half wave lengths long does not avoid infringement:*

Petitioner's argument on this point appears to have two aspects: first, that the patent claims cannot cover

wires which are not an integral number of half wave lengths long because, plaintiff argues (contrary to fact), wires of such intermediate lengths were not disclosed in the application as filed; and, second, that Carter, in distinguishing from the Lindenblad V antenna, limited his own invention to integral half wave length wires.

As to the former, we will show under Point III (which deals specifically with that question) that, contrary to petitioner's position, the original application specifically described the use of wires of lengths *between* integral half wave lengths.

As to the latter aspect of petitioner's argument, it must be borne in mind that the Lindenblad patent failed to disclose, for wires of *any* length, the optimum angle to use between the wires of his V antenna.

What Carter said, when distinguishing his invention from that of the Lindenblad patent during the prosecution of his application, was that Lindenblad did not give "the definite precise *relation* between the angle and the length of the antenna", whereas Carter did. This was expressed in several different ways, as petitioner points out (brief, p. 20). The statement has nothing whatsoever to do with any distinction between integral half wave length wires and wires of other lengths, first because Lindenblad did not give the precise relation for wires of *any* length, and second because Carter *did* give it for wires of *any* finite length and *specifically* (II, 1038, last paragraph) for wire lengths that do *"not correspond to a whole number of half wave lengths."*[25]

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[25]The fact that the wires of four of petitioner's antennas were roughly 7¾ wave lengths long does not indicate any independent development by petitioner; Fig. 38 of plaintiff's Exhibit 20 (II, 585)—published about eight months before petitioner built its V antennas—shows a double-V antenna with wires of that length.

(4) *Petitioner's antennas use the angles specified in the Carter patent:*

Petitioner naïvely states (brief, pp. 19, 25) that none of its antennas "employs the angle called for by the *Abraham* formula." All that petitioner can mean by this is that the Abraham formulas have nothing to do with wires intermediate in length between integral half wave lengths, whereas all but one of petitioner's antennas are intermediate between integral half wave lengths; and that, as to the one remaining antenna, it is eight half wave lengths long and employs an angle between wire and bisector of 22½° instead of the 25° angle recommended by Carter.

Petitioner also argues that its antennas do not employ the Abraham formula "as restated by Carter in empirical form." One fallacy here is that Carter's empirical formula is not a restatement of the Abraham formulas. The Abraham formulas relate only to single wires and, admittedly, are only applicable to them when they are an integral number of half waves long. Even then, the angle of predominant radiation with respect to a wire cannot be directly determined from them. When solved, they give a curve showing the radiation characteristics of a single straight wire in any plane including the wire (Kelley, I, 314, XQ. 1452); to determine the angle, the formula must be maximalized (idem, XQs. 1453-6). Carter's empirical formula, on the other hand, gives, by direct solution, the desired angle and gives it *not only for the limited condition to which the Abraham formulas are applicable* (integral half wave length wires), but also for *all other wire lengths.*

Of course, no different result would be expected from petitioner's insignificant variations from the angles recommended by Carter,—less than ½° in nine out of the eleven

antennas[26] (see Appendix). The largest variation is in antenna No. 8, where an angle of 22½° between bisector and wire was used instead of 25°,—a 10% variation. But in no case did petitioner's angle depart from Carter's (as Lindenblad's did)[27] by so much as to result in predominant radiation in horizontal directions differing from that of the bisector of the angle between the wires, for, admittedly, *all* of petitioner's antennas radiate predominantly in the direction of the bisector (Pratt, I, 203).[28]

As this Court said, on the question of infringement, in *Sanitary Refrigerator Co.* v. *Winters,* 280 U. S. 30, 42:

> "so that if two devices do the same work in substantially the same way, and accomplish substantially the same result, they are the same, even though they differ in name, form, or shape. * * * A close copy which seeks to use the substance of the invention, and, although showing some change in form and position, uses substantially the same devices, performing precisely the same offices with no change in principle, constitutes an infringement. *Ives* v. *Hamilton,* 92 U. S. 426, 430. And even where, in view of the state of the art, the invention must be restricted to the form shown and described by the patentee and cannot be extended to embrace a new form which is a substantial departure therefrom, it is nevertheless infringed by a device in which there is no substantial departure from the description in the patent, but a mere colorable departure therefrom."

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[26]In both of the claims before this Court, the angle is specified as "substantially" that of the empirical formula.

[27]Lindenblad's recommended half angle of just under 6° (which does not vary with wire length or wave length) differs from the optimum angles recommended by Carter, for wires of the lengths suggested by Lindenblad, by from 63 to 75%.

[28]See Pltf.'s Exh. 53 (II, 720) and Deft.'s Ex. CC (II, 897) which show that, using the angle specified in the Lindenblad patent, the predominant radiation goes out in horizontal directions widely separated from that of the bisector. Also, see Kelley, I, 267.

POINT II

The Court of Appeals did not reverse any findings of fact which were made by the District Court on conflicting evidence.

Petitioner seeks to make much of supposed reversals by the Circuit Court of Appeals of Findings of Fact made by the District Court which petitioner says were based on conflicting evidence. This argument is without foundation and cannot stand analysis. The findings which petitioner discusses are all with respect to the *interpretation of written documents* (the Carter patent and his application as filed), and there is no conflict in the testimony, in so far as there is any which bears on these points.

(1) The first findings referred to by petitioner (brief, p. 28) are to the effect that the patent is limited to radiation in the plane of the wires. We have already discussed this subject (pages 26-29, above) and have shown that the experts are in agreement as to the *facts* relating to this subject. The question to be decided is whether or not the patent is to be *interpreted* (in spite of the admitted knowledge of the art) as limited to an antenna that radiates predominantly in the plane of the wires *at all distances and in all positions.*[29]

(2) Petitioner emphasizes the District Court's Finding that petitioner's antenna systems are "radically different" from those of respondent's patents "in structure, principle of operation and instrumentalities". But the evidence on these points was not conflicting.

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[29]This is a question of law. See *Coupe* v. *Royer,* 155 U. S. 565, 579; *Winans* v. *Denmead,* 15 How. 330, 338.

The *structure* of petitioner's antennas and the *instrumentalities* employed were covered by stipulation (see I, 30 and Pltf.'s Exhs. 7 to 13, II, 507-531); as the District Court itself said (II, 1134),

> "*There is no dispute* as to the construction or arrangement of the defendant's antenna systems * * *."

As to the "*principle of operation*" of petitioner's antennas, the experts were again in agreement: see Hogan for respondent (I, 128-129) and Kelley for petitioner (I, 282-283), where he specifically stated that he agreed with Hogan.

The matter that was (and is) in dispute between the parties and the question on which the Court of Appeals differed from the District Court was with respect to *how the Carter patent should be interpreted.*

(3) The third "finding" of the trial court referred to by petitioner (brief, p. 30) is that Carter is confined to a "precise" angle for his V antenna. This also depends upon *interpretation* of the patent and its file history. Consideration of conflicting testimony is not involved.

The trial court's statement that the difference between petitioner's angles and those recommended by Carter "is as great as the difference between Bruce (of the prior art) and Carter" is shown by defendant's Exhibit W (II, 820) to be incorrect;[30] furthermore, Bruce was not "prior art" (see pages 49-51, below).

(4) Petitioner also argues that the Court of Appeals reversed an essential finding of fact made by the trial court on conflicting evidence when it unanimously held

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[30]Two of the antennas shown on Defendant's Exhibit W,—those marked No. 2 and No. 3,—were built *after* this action was instituted; *i. e.*, they are the "rebuilt" antennas of Plaintiff's Exhibit 10. If Exhibit W had shown the *original* antennas Nos. 2 and 3, they would have appeared on the chart exactly on the Carter angle.

(II, 1172) that the original Carter application disclosed the use of wires intermediate in length between integral half wave lengths and the angles to be used for wires of such lengths.

Petitioner seeks to make it appear that there was conflicting testimony as to the interpretation to be placed on Carter's application as filed. But the Carter file wrapper (containing the application as filed, and its history in the Patent Office) was offered in evidence at the close of defendant's case (I, 414) and was never once referred to in the testimony.

As to the trial court's finding that "neither Carter's empirical formula nor Fig. 12 make a correct showing of what happens when the wires are other than exact multiples of half wave lengths", the testimony, when analyzed, does not support it (see footnote 31, page 40, below).

(5) As to the fifth group of findings referred to by petitioner (brief, pp. 32-33),—that no one had ever utilized the subject-matter of respondent's patents,—this, as specifically stated by the District Judge (II, 1156-1157), was based on his interpretation of the patents. Thus what he must have meant was that, on the basis of excluding from the Carter patent antennas located over ground and therefore subject to ground effect, neither party had used the subject-matter of that patent.

POINT III

There was no expansion of the subject-matter of the application for the Carter Patent.

Petitioner argues that the Carter patent is invalid because there was unlawful expansion of the subject-matter of the application. It says that the original application contained no disclosure of the use of antenna wires of

lengths intermediate between integral half wave lengths and that that disclosure was added several years after the application was filed. The District Court sustained petitioner in this argument, but that court clearly must have failed to read the Carter application as filed. On this point, the Court of Appeals specifically found contrary to petitioner's argument, and contrary to the conclusion of the District Court. In its opinion, the Court of Appeals says (II, 1172):

> "Carter's application stated that the invention was applicable to wires of *any finite length*. His *original application* included the empirical formula and the curve of that formula is shown and described.

A comparison of the specification and claims of Carter's application as filed with those of the issued patent will show, without the necessity of argument, that the use of antenna wires intermediate in length between integral half wave lengths was described in the application as filed and that petitioner's position on this point is baseless. For convenience in making such a comparison, we set forth below, in parallel columns, extracts from the Carter application as filed and the corresponding portions of the Carter patent as issued.

Extracts from Carter Application as Filed	Corresponding Extracts from the Carter Patent
"Still a further object of the present invention is to disclose the proper angle for conductors or radiators either an even number of half wave lengths long or an odd number of half wave lengths long, and, in general to disclose the angle for best directional propagation for *wires of any finite length.*" (II, 1032.)	"Another object of the invention is to disclose the angle for the best directional propagation for open-ended *wires of any finite length,* preferably longer than the operating wave length, having standing waves thereon and arranged in the manner proposed." (II, 499, lines 29-34.)
"Figure 12 is a graph showing the proper relationship, according to the present invention,	"Figure 12 is a graph showing the relationship between the length of one of a pair of con-

EXTRACTS FROM CARTER APPLICATION AS FILED (cont.)

between the length of a single conductor of a pair of conductors and the angle to be given it relative to a desired direction of propagation." (II, 1034.)

"**Moreover, it should be clearly understood that the wires of each unit can be of any length whatsoever** provided they are placed at the correct angle for their length. For best tuning, the total over-all length of both of the wires and the 'U' loop terminating them should be effectively an integral number of half wave lengths, but, **the portion forming the radiation element can be of any length.** The law, giving the correct angle for *lengths between odd and even number of half wave lengths, is* not given due to its complexity but, the empirical formula and the curve of figure 12 will be found accurate for all practical purposes, *where the length of wire dealt with does* **not** *correspond to a whole number of half wave lengths.*" (II, 1038.)

CLAIM 19:

"An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice $50.9\left(\frac{l}{\lambda}\right)-0.513$ degrees." (II, 1047.)

CORRESPONDING EXTRACTS FROM THE CARTER PATENT (cont.)

ductors and half the angle between them for obtaining maximum radiation along the bisector of said angle." (II, 499, line 109 to p. 500, line 3.)

"It is to be further understood that the wires of each unit can be *of any desired length* provided they are placed at the correct angle for their particular length. For best tuning, the total over-all length of both of the wires and the U loop terminating them should be effectively an integral number of half wave lengths, although *the portion forming the radiation element can be of any length.* The law giving the correct angle for *lengths between odd and even number of half wave lengths* is not given herein due to its complexity but the empirical formula and the curve of Figure 12 will be found accurate for all practical purposes, *whether or not the length of wire dealt with corresponds to an integral number of half wave lengths.*" (II, 501, lines 8-23.)

CLAIM 15:

"An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)-0.513$$

degrees, l being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length." (II, 503.)

Furthermore, both the original application as filed and the patent as issued contain the empirical formula[31] and Figure 12, both of which, as the application as filed specifically stated. "will be found *accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths*" (II, 1038).

The Carter application as filed was just as specific as the issued patent in respect to the use of wires not an integral number of half wave lengths long. *If it had issued exactly as filed, it would have described and claimed petitioner's antennas.* Claims 15 and 16, now before this Court, were claims 19 and 20 of the application as filed. Neither those original claims nor the issued claims are limited to

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[31] Petitioner has criticised Carter's empirical formula on the ground that it is an unwarranted extension of the old Abraham formulas. Petitioner's argument is to the effect that the Abraham formulas are valid only with respect to a wire which is an integral number of half wave lengths long; that Carter's formula is derived by interpolation between the points for which the Abraham formulas are valid; and that, therefore, Carter's formula must be wrong. However, petitioner's expert merely said that Carter's formula "doesn't show *exactly* what the curve should be for lengths which are not exact multiples of a half wave length" (I, 238); and he could not say to what extent it was wrong (I, 315) and was not even willing to say that it was in error by as much as one-tenth of a degree. Carter did not say that the formula was rigidly correct but merely that it was "accurate *for all practical purposes*" (II, 1038). Petitioner's expert never denied this; in fact, he could not do so because petitioner's antennas, all but one of which utilize wires intermediate in length between integral half wave lengths, use almost exactly the angle of the Carter empirical formula. As the Court of Appeals stated with respect to petitioner's argument on this point (II, 1172-1173):

> "The effect of this argument is to show that as to wires which are not an integral number of half waves long, the recognition that there was for such wires an angle of predominant radiation was not obvious but was covered by Carter. Carter found that interpolation between these lengths was sufficiently accurate for practical purposes and disclosed the angles to use for V-antennas using wires of intermediate lengths. Appellee [petitioner] followed this disclosure and accomplished the results set forth by Carter."

wires an integral number of half wave lengths long and there is no basis for so limiting them.

POINT IV

Under the circumstances, no supplemental oath was necessary.

Under its Point IV, petitioner argues that, because of the alleged broadening amendment, the patent is invalid because, in its broadened form, it was not subscribed or supported by the oath of the inventor.

But the amendments, as we have shown, were not broadening but were merely clarifying; there was no change of subject-matter. Under such circumstances, no supplemental oath is necessary since the original oath covers the subject-matter of the issued patent.[32]

POINT V

The Carter Patent is valid over the prior art.

The trial court did not mention any of the foreign patents now relied on by petitioner. On the other hand, the Court of Appeals discussed all of them, and held specifically (II, 1175):

> "Critical examination of prior patents and uses finds nothing invalidating the Carter invention * * *."

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[32] *O. K. Jelks & Son* v. *Tom Huston Peanut Co.*, 52 Fed. (2d) 4, 6 (C. C. A., 5th Circ.; cert. denied, 284 U. S. 686); *Richardson Co.* v. *Ruberoid Co.*, 30 Fed. (2d) 232, 234 (C. C. A., 2nd Circ.; L. HAND, *J.*); *Keller Bros. Co.* v. *Crucible Steel Co.*, 297 Fed. 39, 43 (C. C. A., 3rd Circ.; MORRIS, *J.*). See also *De la Vergne Co.* v. *Featherstone*, 147 U. S. 209, 227.

(1) The Abraham Articles of 1898 and 1901

The Abraham articles are mathematical analyses of the radiation from a *single* straight wire in free space. They nowhere suggest any possible utility for the analyses in the construction of a directive antenna, and do not suggest combining two or more wires in any arrangement, or make any analyses of the resultant radiation from any such combination (I, 450-451, Qs. 1001-4).

It is possible to determine, from the formulas given by Abraham, the angle between a single wire an *integral* number of half waves long and the directions of the predominant radiation therefrom, but the formulas as derived by Abraham are not "general" formulas (as petitioner's brief at p. 44 alleges that they are). The Abraham formulas apply only to the special lengths of single wires stated, whereas Carter's empirical formula applies to wires of any length in V formation.

It remained for Carter to conceive of placing two long wires at an angle determined by their length and the wave length used and then to determine the surprising concentration of radiation resulting from a properly arranged V antenna, and to state a formula that would determine the desired angle with accuracy quite sufficient for communication purposes whether or not the length of the antenna wire is made up of exact multiples of half wave lengths of the current.

The holding of the Court of Appeals (II, 1174-5) very clearly and concisely disposes of these articles as a defense:

> "The Abraham articles of 1898 and 1901 with the formula suggested, although 30 years old, had never been utilized. From that time was the entire period of the development of the radio art. While his formulas unquestionably had useful scientific interest to radio

engineers, they failed to teach how to construct a directive antenna. *Nothing in them suggests the inventions of Carter.*"

(2) **The Bethenod French Patent No. 596,737**

This patent discloses an admittedly old type of long-wave antenna,—namely, two horizontal *networks* of wires, one placed above the other, the two being fed in phase opposition. Bethenod's stated invention was the use of this old, long-wave antenna as a short-wave antenna.

Petitioner says that this French patent "discloses a short-wave *directional* system". But all that the *patentee* says is (II, 826) that:

> "Obviously, numerous other variants are *possible*. Particularly the two networks 2 and 3 of Fig. 1 may be arranged vertically or even inclined not only with respect to the ground, but also with respect to one another so as to obtain directional effects either in the horizontal plane, or in the vertical plane, or in both planes."

Both experts agree (Kelley, I, 320; Hogan, I, 445) that this suggestion of Bethenod can be followed and still have all the wires of his antenna system *parallel* to each other. This mere vague suggestion, which taught nothing to the art, is insufficient to invalidate a later patent clearly disclosing a meritorious invention.[33]

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[33]See *Eames* v. *Andrews*, 122 U. S. 40, 66, where this Court said (quoting from *Seymour* v. *Osborne*, 11 Wall. 516, 555):

> "Patented inventions cannot be superseded by the mere introduction of a foreign publication of the kind, though of prior date, unless the description and drawings contain and exhibit a substantial representation of the patented improvement, in such full, clear, and exact terms as to enable any person skilled in the art or science to which it appertains, to make, construct, and practice the invention to the same practical extent as they would be enabled to do if the information was derived from a prior patent.

(*Footnote continued on next page*)

Bethenod also fails to disclose the Carter invention because he does not disclose *long* wires (I, 444) and because his antenna system is composed of *networks* of wires rather than of simple, straight wires.

Petitioner finds Carter's invention in this Bethenod patent because (petitioner says) "the angle must be chosen in accordance with the well-known Abraham formula to insure best radiation in the desired direction", stating then that one skilled in the art "would obviously employ it". (Brief, p. 44.) With this latter statement we most emphatically disagree. It is supported solely by the testimony of petitioner's expert; on the other side of the scale, there is the testimony of *petitioner's* witness Bruce, who admittedly was "one skilled in the art". He had a form of V antenna in May, 1926 (II, 907), was acquainted with the Abraham or equivalent formulas (I, 366-367), and failed to see that one could be used in connection with the design of the other until 1930,—*after* the Carter invention had been made. The testimony of this highly skilled, practical worker in the art—binding, as it is, on petitioner—far outweighs the largely argumentative testimony of its expert, who was primarily versed in theory (I, 268-269).

(3) The Bethenod French Patent No. 625,293

It is only necessary to examine the drawing of this patent (II, 830) to see that it has no bearing on the Carter invention. The patent discloses a *single-wire* antenna. The novelty of the arrangement is in the feed-system, not in the antenna. *Bethenod does not state or suggest that the antenna that he shows is directive;* he merely says that direc-

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Mere vague and general representations will not support such a defence, as the knowledge supposed to be derived from the publication must be sufficient to enable those skilled in the art or science to understand the nature and operation of the invention, and to carry it into practical use."

tivity can be secured by the use of *several* separate antennas of the same kind, suitably positioned in reference to one another (I, 450).

(4) The Levy French Patents

Petitioner's statements (brief, pp. 45-6) that the teaching of these patents is "in all essential respects, the same as petitioner's antennas" and that Levy "explains the directional radiation that is obtained from petitioner's antennas" can only mean that Levy explains the effect of ground in canceling, at a distance, the horizontal radiation and augmenting the tilted radiation.

Petitioner says that certain quoted portions of the Levy patent contain "a complete definition of the directional radiation that is obtained from petitioner's antennas". Levy here says that the predominant radiation from his antenna is in "the vertical plane *perpendicular to the axis* of the radiator". This is not true of the antenna of the Carter patent, or of respondent's or petitioner's antenna structures; all of them radiate predominantly in the vertical plane which *includes* the axis of the radiator system.

Furthermore, Levy's wires were *short*,[84] and he failed to appreciate or suggest any advantage in the use of long wires, which constitute the fundamental antenna units of the Carter antenna.

Also, he showed *networks, each composed of three wires;* the radiation from such networks would be uncertain because the phasing and the relative position of the wires are not definite (I, 440-441).

Like Bethenod, Levy is *totally indefinite as to the obtaining of directive action* with his antenna. All he says (II, 867) is:

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[84]The wires are only a quarter of a wave length long (Hogan, I 440; Kelley, I, 253, 329).

> "In the first place, it is desirable to point out that *it is possible,* instead of adopting the arrangements described in the main patent, *to conceive of* different variations which may offer advantages in certain cases, particularly where it is desired to radiate energy in a given direction."

And, of course, Levy does not disclose or suggest the relation taught by Carter, or *any* relation, between wire length, wave length, and angle. As a matter of fact, the best directivity (such as it is) obtainable with Levy's antenna is obtained when his two networks are arranged end to end and in a straight line,—in which case they become similar to the simple dipole antenna,[35] which was much discussed in the record and was a well known antenna in the prior art (I, 73-75, 81).

(5) The Lindenblad V Antenna Patent

Petitioner argues (brief, p. 47) that "the art knew that the wires of the [Lindenblad V] antenna *must* be arranged in accordance with the Abraham formula for best radiation" (emphasis is petitioner's). The proofs are to the contrary. For example, Bruce, a skilled worker in the art, who knew of the Abraham formulas, and experimented with V antennas, showed no appreciation of what petitioner now says was known in the art. (See our discussion of Bruce's work at p. 44, above and pp. 49-51, below.)

This argument of petitioner that there was no invention in what Carter did over Lindenblad is one frequently met in patent cases. As this Court said in *Diamond Rubber Co.* v. *Consolidated Rubber Tire Co.,* 220 U. S. 428, at page 435:

> "*Knowledge after the event is always easy,* and problems once solved present no difficulties, indeed, may be represented as never having had any, and expert witnesses may be brought forward to show that

[35] See Pltf.'s Exh. 51, II, 715; Hogan, I, 441-442.

> the new thing which seemed to have eluded the search of the world was always ready at hand and easy to be seen by a merely skilful attention. But the law has other tests of the invention than subtle conjectures of what might have been seen and yet was not. It regards a change as evidence of novelty, the acceptance and utility of change as a further evidence, even as demonstration."

As we have pointed out, Lindenblad did not consider the angle between the wires to be of importance. Thus he said in his patent (II, 488, lines 115-119):

> "The divergence [between the wires] should preferably be *fairly gradual,* and the spacing at the open end, while variable over a great range, should be in the neighborhood of a fifth of the length"—

which means an angle of about 12°, regardless of wire length and wave length (I, 451). The wire lengths suggested by Lindenblad are "of the order of magnitude of five to ten waves long" (II, 488, lines 120-121). The optimum angles between wires of these lengths, as taught by Carter, vary from 45° to 32°.

Carter's file history does not support petitioner's statement that Carter's invention consisted solely in the application of the old Abraham formula to determine the precise angle of the Lindenblad V antenna. Carter determined, as we have pointed out before, the proper *co-ordination of wave length, wire length, and angle for securing optimum directivity from a V-type antenna.* He further determined the formula that correctly states the relation between these three variables for securing maximum results regardless of wire length and of wave length.[36] If any one of these

[36]Admittedly, the prior art, Abraham, single-wire formulas taught nothing whatsoever about radiation from wires not an integral number of half waves long; for wires of those lengths, there *was* no Abraham formula,—nor any other knowledge as to how such wires radiated or even that there were predominant directions of radiation from such wires. (See page 33, above.)

variables is changed, one or both of the others must be changed to maintain optimum results. Neither Lindenblad nor any of the alleged users of V antennas had any conception whatever that any such co-ordination was necessary or even beneficial or indeed any idea of a co-ordination.[37]

That Carter obtained a new result, as compared to what Lindenblad had done, is shown by Defendant's Exhibits CC and DD (II, 897, 898). These are plots of the radiation from antennas described by Lindenblad and show that the predominant radiation does not go out on the bisector of the angle between the wires but in directions widely departing therefrom.[38] Respondent's Exhibit 53 compares the radiation from a "Lindenblad V antenna" (II, 720) with that from a Carter two-wire V antenna (II, 722), with the same power input and on the same scale (I, 453). The difference is striking.

The opinion of the Court of Appeals concisely distinguishes the disclosure of the Lindenblad patent from the Carter invention. It says (II, 1169):

> "*Lindenblad stated nothing* as to the advantages of any specific angle between the wires of his V-antenna and as to *any relation between preferred angle, wire*

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[37]The Lindenblad patent was cited by the Patent Office as a reference against Carter (II, 1090) but was eventually withdrawn. Under such circumstances, the *prima facie* validity of the Carter patent is greatly strengthened. *Gairing Tool Co.* v. *Eclipse Co.*, 48 Fed. (2d) 73, 75 (C. C. A., 6th Circ.); *Artcraft Silk Hosiery Mills* v. *Gotham Co.*, 72 Fed. (2d) 47, 48 (C. C. A., 3rd Circ.; certiorari denied, 293 U. S. 595); *Stevens* v. *Carl Schmid, Inc.*, 73 Fed. (2d) 54, 56 (C. C. A., 2nd Circ.; certiorari denied, 294 U. S. 721); *Chesapeake & O. Ry. Co.* v. *Kaltenbach*, 95 Fed. (2d) 801, 804 (C. C. A., 4th Circ.).

[38]As petitioner's expert said, referring to Lindenblad's antennas (I, 267):

> "not only does predominant radiation not take place along the axis [bisector] of the conductor system, but the predominant radiation is in the directions which lie wholly outside of the wires forming the system."

length, and wave length. He said that the spacing between the ends of the wires, 'while variable' over a long range, should be in the neighborhood of a fifth of the length *which, regardless of wave lengths and wire lengths,* means an angle under 12° between the wires. The wire length suggested is of the order of five or ten waves long. *Carter* taught 12° is not the most desirable angle for a V-antenna having wires of these lengths. He developed the theory of long wire V-antennas and taught how to construct them so as to secure maximum directivity by *co-ordinating the angle, wire length, and wave length.*"

(6) The Prior Work of Bruce

Petitioner appears to have abandoned Bruce as a prior inventor of the subject-matter of the Carter patent. (See its brief, pp. 47-8.) The reason becomes apparent when the true effect of Bruce's testimony is appreciated.

Bruce was a skilled worker in the art, a graduate electrical engineer, to whom outstanding honors have been awarded for his work in short-wave, directional antenna development (I, 376-377). He commenced his research work in this field in 1924 (I, 352) and, over the next six years, he carried on "a vast amount of work" (I, 367, 373-375, 377, 381, 398-399), practically all for the purpose of developing a directive antenna (I, 353). This work was all done for the American Telephone and Telegraph Company (I, 377).

Before commencing his work, Bruce familiarized himself with the literature on the subject (I, 353, 378) and was familiar, at least as early as 1926, with the Abraham formulas as set forth in the Levin and Young article (I, 366-367, 381; II, 903).

In May, 1926, he tested an antenna composed of two long wires, one horizontal and the other inclined upward from it in the same vertical plane,—*i. e.*, having the form of

a V (II, 907). The angle between the wires (as may be computed from the constants given) was 9½°,—even smaller than the angle suggested by Lindenblad. The correct angle, as determined from Figure 12 of the Carter patent, would have been 68°.

These experiments of May, 1926, are significant. They show that Bruce had, as early as 1926, experimented with an antenna composed of a pair of simple, straight, long wires arranged in a common plane. Although he erected and tried out such an antenna, *he totally failed to appreciate the possibilities of a V antenna* with proper co-ordination of wire length, wave length, and angle between the wires. *Instead, he turned away from the simple, two-wire V arrangement and never returned to it.* He went to single tilted wires (either straight, or bent in the middle to form an *inverted* V, fed at one end; Bruce, I, 380, 387) and *four years later, in 1930, after* Carter had invented the subject-matter of his patent,[39] devised his *first* commercially successful antenna,—the horizontal *rhombic* (diamond) antenna of his British patent No. 392,201 (Pltf.'s Exh. 41, II, 634-637).

In most patent cases, the Court can do little more than guess, on the basis of conflicting expert testimony, what the mythical "man skilled in the art" would have done with the prior art in front of him. But in the present case, petitioner's own testimony (that of Bruce and his co-workers) shows affirmatively what a man *highly* skilled in the art and working on the identical problem that the patentee was working on was able—or, rather, *un*able—to do, with the prior art (as represented by the literature and by his own

[39]Prior to March, 1930, Carter had conceived of, disclosed to others, built, and tested his V antenna; and commercial adoption followed quickly (*I*, 421-438). Petitioner has never questioned the adequacy of this proof.

work) before him. And the history of what the art actually did in commercial practice (set forth at pp. 6-9, above) supports our contention that Carter, when he invented the V antenna of his patent, accomplished something of real novelty and utility: the history of the art is entirely inconsistent with petitioner's position that the invention was obvious. The evidence in the present case on the question of invention is of the kind that is most satisfactory and convincing.[40]

POINT VI

Reply to other specific matters in petitioner's brief.

(1) *Carter's suggestion of tilting his antenna does not indicate that he expected predominant radiation, at all distances, in the plane of the wires:*

Petitioner argues (brief, p. 13) that the Carter patent "states (Vol. II, p. 502, ll. 27 *et seq.*) that when it is desired to radiate *at an angle* to the earth's surface it is necessary to tilt the wires from their *normal horizontal position* to the *required angle to the earth,*" etc. (Emphasis is petitioner's.)

But this is *not* what the patent says. It merely says that "it may often be found desirable" to tilt the antenna "*towards* the *direction* in which the beam of energy is to be propagated." Carter says, in effect, that it may be desirable to have the radiation go out at a higher angle than will result from a horizontal antenna; that, under those circumstances, the antenna should be tilted "*when* it is desired to radiate at an angle to the earth". The ac-

[40] See *Eibel Process Co.* v. *Minnesota, etc., Paper Co.*, 261 U. S. 45, 63; *Carnegie Steel Co.* v. *Cambria Iron Co.*, 185 U. S. 403, 429-430, 446.

curacy of Carter's teaching in this respect is not questioned (I, 343, XQ. 1755).

(2) *There is no "admission" in Carter patent No. 2,027,020 that the patent in suit is limited to radiation in the plane of the wires:*

Petitioner argues (brief, pp. 13-14) that a *later* Carter patent constitutes an admission that the patent in suit was intentionally and deliberately limited to radiation in the plane of the wires. However, all that the later patent says is that, as we admit, the patent before this Court does not *describe* the well-known effects of ground.

Furthermore, as was held in *Deitel* v. *Unique Specialty Corp.*, 54 F. (2d) 359, 360 (C. C. A., 2nd Circ.), with respect to statements made by a patentee in a later filed application:

> "We cannot regard either the patent or what he said as material to the proper interpretation of the claims in suit. *At most they could be regarded as no more than admissions, and as such they were not material to the construction of the patent in suit,* a formal written instrument, whose meaning we must find from its terms."

(3) ***What Carter invented was an antenna, not a formula:***

Petitioner (brief, p. 17) says that we have

> "conceded • • • that there was no element of novelty or invention in the utilization of the Abraham formula, and advanced the *empirical* statement of the Abraham formula as Carter's invention." (Emphasis is petitioner's.)

This is a gross misstatement of our position. We have *always* asserted that what Carter invented was an *antenna.*

He merely utilized the Abraham formulas in mathematically analyzing and explaining a theory of results he got from his new structure. Carter did not patent or attempt to patent any formula.

(4) *Petitioner's Exhibit X does not show that Carter's empirical formula is incorrect:*

Petitioner says (brief, p. 22) that its Exhibit X (II, 821) "graphically illustrates" that Carter's empirical formula is not valid. Lest the Court be misled by the appearance of the curve of this exhibit, we wish to point out that Exhibit X [illegible] curve of "radiation resistance" in relation to wire length. But radiation resistance is one thing and angle of predominant radiation is another thing. Petitioner's expert discussed the radiation resistance curve *not,* as petitioner has said, to demonstrate that Carter's empirical formula was incorrect, but to show some supposed advantage in petitioner's use of wires an odd number of quarter wave lengths long (I, 239-244). Kelley never said that the radiation resistance curves showed that Carter's empirical formula for the *angle* was incorrect.

(5) *Petitioner does not employ old V-Type Antenna Structures:*

Petitioner states (brief, p. 23) that it

"employs the *old* V-type antenna structures."

However, petitioner has combed the art and it has been unable to show a single description of a V antenna employing the co-ordination of elements taught by Carter. In this connection, we note petitioner's statement (brief, p. 11) that:

"the art prior to the Carter patent in suit disclosed *a multitude of types and arrangements of antenna*

> *wires,* singly or in multiples, alone or with reflector, vertically, horizontally or angularly arranged towards the earth or towards each other."

This may be true, but petitioner's failure to use any of these prior antennas and its adoption of the Carter antenna just as described in plaintiff's Exhibit 20, in the Carter application as filed, and, later, in the Carter patent, speaks eloquently of the novelty and utility of Carter's invention.

(6) *There is no evidence that petitioner "intentionally" or "deliberately" sought to obtain a different result in constructing its antennas:*

At page 24 and elsewhere in its brief, petitioner refers to the testimony of its expert Kelley to show that, in constructing its antennas, certain results were sought *"intentionally"* and *"deliberately"* (emphasis is petitioner's). Although Kelley made such statements on his direct examination, on cross-examination he repeatedly disavowed any knowledge as to why petitioner's antennas were built as they were (I, 269-270, 273); he said (XQ. 1067):

> "I have no knowledge of when they were designed, who did it, or what they did. I have only seen them as they exist."

Petitioner's Chief Engineer, Pratt, under whose direction petitioner's antennas were designed and installed (I. 201, 204), also testified for petitioner. If petitioner constructed its antennas in any special way to secure any special results other than those taught by Carter, Pratt was the only witness competent to testify to that fact. He was not asked for any such testimony, and gave none.

(7) *The Carter patent is not a "paper" patent:*

At several places in its brief (*e. g.*, pp. 26, 52), petitioner refers to the Carter patent as a "paper" patent, as one "unused by anyone", etc. We have shown that not only respondent, but also petitioner, *has employed the exact structure described in the patent.* The record shows petitioner had erected eleven such antennas (II, 622), and respondent forty (I, 44) at the time of the trial.

(8) *Adamson* v. *Gilliland does not apply:*

Petitioner (brief, p. 27) refers to the decision of this Court in *Adamson* v. *Gilliland,* 242 U. S. 350, as showing that the Circuit Court of Appeals was in error in reversing the District Court. We have shown, however, that the "findings" of the trial court were chiefly *interpretations* of written documents or based upon such interpretations, and that they do not depend upon conflicting testimony or upon the credibility of witnesses. Under such circumstances, they do not have the weight ordinarily attaching to findings of fact. *Morimura, Arai & Co.* v. *Taback,* 279 U. S. 24, 33.

(9) *The number of witnesses:*

As to petitioner's intimation (brief, p. 28) that the trial court had to resolve conflicts involved in the testimony of "more than a score of witnesses", we note, first, that only fifteen witnesses testified and, second, that, of these, nine testified solely with respect to Bruce's alleged prior invention or Carter's date of invention, four testified solely with respect to facts as to which there was no conflict, and only with respect to the testimony of the remaining two (the experts, Hogan and Kelley) could there be said to be any conflict. The experts were in agreement as to

substantially everything except the *interpretation* of the patent and the pertinency of certain prior art.

We definitely dispute the assertions of petitioner set forth in the last paragraph on page 33 of its brief. As to the more important "findings" of the trial judge, we submit there is *no* competent testimony consistent therewith.

(10) *The art's knowledge of "Reflector Effect" does not affect the validity of the Carter patent:*

At pages 40-42 of its brief, petitioner goes to great pains to show that, as has never been questioned by us, the so-called "reflector effect" was known before Carter invented his V antenna. Petitioner's argument appears to be that claim 16 of the Carter patent covers the combination of his new V antenna with a prior art "reflector" and that the claim is therefore invalid, citing the decisions of this Court in *Lincoln Engineering Co.* v. *Stewart-Warner,* 303 U. S. 545, and *Powers-Kennedy Contracting Corp.* v. *Concrete M. & C. Co.,* 282 U. S. 175. However, neither of these decisions is applicable to the present case.

There is no prior art element in Carter's claim 16. What the claim covers is two of his *new* V antennas, properly spaced with respect to each other to secure unidirective action. The combination claimed, both in its entirety and in its component parts, is a *new combination.*

The type of claim criticized in the *Lincoln Engineering* case was one which sought to cover an *old combination,* one element of which had been improved. The reason why such a claim is void is that the patentee thereby seeks,

> "by the use of a combination claim, to *extend the monopoly* of his invention of an improved form of chuck or coupler *to old parts or elements* having no new function when operated in connection with the coupler • • •." (Page 552.)

Carter's claim 16 cannot extend his monopoly because each of the elements of the claim is separately covered by, for example, claim 15.

In the *Powers-Kennedy* case, the claim under consideration was held invalid because

> "It consists of a combination of elements *all of which were old in the art.* * * * Neither the combination of *old elements or devices* accomplishing no more than an aggregate of old results [cases cited] nor the use of an *old apparatus or appliance* for a new purpose [case cited] is invention." (Page 186.)

All of the elements of Carter's claim 16 (namely, two of his new V antennas) were new with him; therefore, the holding of this Court in the *Powers-Kennedy* case also has no application to the present case. The subject-matter of claim 16 is a new antenna, not an old combination.

CONCLUSION

The accused antennas of petitioner are identical in structure, position, and actual effectiveness in use with antennas described in the Carter patent in suit. The trial court's decision of non-infringement was based on its interpretation of the patent in suit as being limited to a V antenna which, under all conditions and at all distances, concentrates radiation in the plane of the wires and on the bisector of the angle of the V, and upon its interpretation of Carter's application as filed.

The trial court did not find the Carter patent anticipated by any of the prior art, or invalid thereover. The Court of Appeals specifically held that the prior art does not anticipate. It also specifically held that the trial court's reading of the Patent Office history of Carter's application, resulting in a conclusion that there had been an improper expansion of the disclosure by amendment, was erroneous.

When the Carter patent and the original application therefor are correctly interpreted, the basis for the trial court's decision entirely vanishes. The errors of that court were mistakes of interpretation of documents and were corrected on appeal. That being so, and it having been shown in addition that the history of this patent in the art demonstrates that an invention of high order was made, we think the statement of the Court of Appeals, in concluding its opinion, is an apt conclusion for this brief. That Court said (II, 1175):

> "The problem solved here was of long standing and it was an eminently successful solution. Critical examination of prior patents and uses finds nothing invalidating the Carter invention and it shows a substantial accomplishment."

The decision of the Circuit Court of Appeals for the Second Circuit should be affirmed.

Dated, December 5, 1938.

Respectfully submitted,

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Harry Tunick,
Counsel for Respondent.

APPENDIX.

Angles Utilized in Petitioner's V Antennas Compared to Angles Recommended by Carter.

Petitioner's Antenna No.	Wire Length in Wave Lengths	Angle Between Wire and Bisector—*as used by Petitioner*	*as Recommended by Carter*	Difference
	(II, 530)	(II, 530)		
1 (double V)	6.21	20°	19.93° (I, 162)	+0.07°
2* (single V)	7.74	17.5°	17.8° (I, 139)	—0.3°
3* (single V)	7.69	17.86°	17.88° (I, 160)	—0.02°
4 (double V)	7.69	17.5°	17.88° (I, 162)	—0.38°
5 (double V)	6.21	20°	19.93° (I, 162)	+0.07°
6 (double V)	7.67	17.5°	17.9° (I, 162)	—0.4°
7 (double V)	6.24	20°	19.88° (I, 162)	+0.12°
8 (double V)	4.	22.5°	25° (I, 151)	—2.5°
9 (double V)	7.70	17.5°	17.86° (I, 162)	—0.36°
10 (double V)	7.17	17.5°	18.53° (I, 162)	—1.03°
11 (single V)	7.69	17.5°	17.88° (I, 160)	—0.38°

*Antennas Nos. 2 and 3 above referred to are those antennas in their original form.

FILE COPY

IN THE

Supreme Court of the United States

October Term, 1938

No. 347

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

REPLY BRIEF FOR PETITIONER

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IN THE

Supreme Court of the United States

October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

REPLY BRIEF FOR PETITIONER.

Respondent's brief (*e. g.* p. 15) makes it perfectly clear that all that the Carter patent purports to add to the prior Lindenblad V-antenna patent (Vol. II, p. 486) is, as stated in our main brief (p. 16), the means for determining the *specific* angle of the V, to obtain the *greatest* concentration of radiation in the plane of the wires and along the bisector of the V.

Respondent's brief likewise makes it clear that the only manner in which this angle can be determined is by a mathematical formula, either as *accurately* stated (*e. g.* claims 9 *et seq.*) or as *empirically* stated (*e. g.* claims 15 *et seq.*).

Thus, the conclusion is inescapable that Carter's sole contribution is a mathematical formula. Indeed, that was the *sole* inventive idea stressed in the Carter application to secure its allowance over the prior Lindenblad patent

(see our main brief, p. 20), and advanced by respondent's expert at the trial of the case (Vol. I, p. 122, fol. 178; see also the decision of the District Court, Vol. II, p. 1145, fol. 1362, quoted in our main brief, pp. 15 and 16).

Because it was conclusively proven that the mathematical formula was originated and published by Abraham, respondent *now* admits that the mathematical formula was not Carter's invention. Indeed, the formula is now disavowed, and the statement is made (p. 52):

> "We have *always* asserted that what Carter invented was an *antenna*. He merely utilized the Abraham formulas in mathematically analyzing and explaining a theory of results he got from his new structure. Carter did not patent or attempt to patent any formula." (Emphasis respondent's.)

The formula being the *only* thing which purports to differentiate the Carter patent from the prior Lindenblad patent, respondent seeks to minimize the foregoing admission by contending that the *empirical* statement of the formula in claims 15 and 16 here in suit substantially and materially differs from the Abraham formula. The Carter patent makes no such distinction. Indeed, the Abraham formula literally forms the subject matter of some of the claims of the patent originally in suit but now abandoned. This fact alone completely refutes respondent's assertion, quoted above, that—

> "Carter did not patent or attempt to patent any formula."

Besides, as we have pointed out in our main brief (pp. 43, 44), it has been conclusively established that the reduction of a rigorous mathematical formula into *empirical* form is an every day occurrence in all lines of engineering;

the latter can be no more accurate than the rigorous formula from which it is derived.

In consequence, this case and this brief could stop here. However, because respondent has unwarrantedly criticized portions of petitioner's main brief, and has advanced arguments built on premises for which there is no foundation in fact or in the record, we feel compelled to make comment thereon in the order in which they appear in respondent's brief, for fear our silence will be misunderstood.

Respondent's criticism of our "Statement of the Case" (Brief pp. 2-4).

Respondent advances a number of enumerated criticisms, the first three of which imply that this Court should disregard matters that for years have been of public as well as of judicial knowledge. Respondent is notoriously the active head of the so-called "Radio Trust" or "Patent Pool", as this and other courts have frequently had occasion to comment upon.* Under these circumstances, while we can well appreciate why respondent should desire to hide the fact, we fail to understand why respondent does not realize the futility of the attempt to do so.

Also, we cannot pass without challenging the gratuitous statement in respondent's brief (p. 4), that the stipulation by which the careful and extensive opinion of the District Court was accepted as the findings of fact and conclusions of law in the case, was—"merely for *petitioner's*

* See the cases cited in footnotes 1 and 2, page 3 of our main brief, where these facts were before the Court. These cases have been cited by this Court, *e. g. American Developments Corp.* v. *Carbice Corp.*, 283 U. S. 27. This subject matter, evidencing knowledge by this Court, is discussed in the minority opinion in *General Talking Pictures Corp.* v. *Western Electric Co. et al.*, 304 U. S. 175.

convenience and at its request".* The absurdity of this statement is best demonstrated by the fact that petitioner was the successful litigant in the District Court, the bill of complaint as to all patents having been dismissed for "want of equity" (Vol. II, p. 1158). Further proceedings in the cause were had solely by *respondent's* appeal. We can conceive of no circumstance by which *petitioner's* "convenience" could have been or was served in any respect, and respondent states none.

Respondent's discussion of prior commercial forms of directive antennas (Brief pp. 6-10).

Respondent starts its discussion of this subject by recognizing that the problem of directive wireless signalling was one of the oldest in the art. Reference is made to Brown's work in 1899, and then to the Marconi beam structure which is characterized (p. 7) as

> "highly directive, and very efficient for concentrating the radiated energy in the direction for which it was intended."

This forms an interesting background to a consideration of the opinion of the Court of Appeals below, which was predicated upon the belief (Vol. II, p. 1168, fol. 1042) that no successful use of directional wireless occurred "until antennas made under the patents here to be considered were built".

By reciting that the Marconi beam antenna cost $175,000; the Models B and C antennas, $30,000 and $40,000 respectively; and the Model D antenna, $5,000, respondent seeks to imply, without the direct assertion, that the Carter patent is responsible for these enormous savings.

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* Italics ours throughout unless otherwise stated.

It is significant that throughout this discussion respondent takes pains to avoid any reference to the prior V-antenna structure of the second Lindenblad patent.

The Lindenblad V-antenna, and not the Marconi beam, or even Models B and C, is the bench mark from which must be measured any alleged saving in costs by the Carter antenna structure. Since, concededly, the only possible difference between Carter and Lindenblad is in *the angle of the V*, there can be no difference in cost between them. Mere comparison of Figs. 1 and 2 of the Lindenblad patent with Fig. 2b of the Carter patent will demonstrate this.

The alleged success of the Carter Model D Antenna (Brief p. 10).

Petitioner does not question that respondent had in operation an antenna which it identified as Model D, but that does not prove commercial success for the Carter patent.

Respondent says that the most "casual" inspection of Carter's description of the Model D antenna shows that it is the antenna of the Carter patent. *Only* a "casual" inspection would convey that idea; a *careful* inspection reveals their fundamental differences.

The patent, on the one hand, is *expressly* directed and confined to radiation *in the plane of the wires on the bisector of the V*. This can be accomplished only by the use of the Abraham formula, and by avoiding ground effect, which alone is responsible for radiation *at an angle* to the plane of the wires. Respondent concedes this on page 15 of its brief, but strenuously denies it later (p. 26). The patent itself points out (*e. g.* Vol. II, p. 501, line 24) that radiation at an angle is "undesired" and is avoided.

As distinguished from this, the commercial Model D antenna of respondent, described in the I.R.E. article, does *not* radiate in the plane of the wires (see for example Fig. 48, Vol. II, p. 593).

It will be seen, therefore, that respondent itself does not employ the Carter patent in its commercial operations, and rather than constituting support for the patent, the commercial Model D antenna, which respondent stresses, is an emphatic and most convincing condemnation thereof.

Respondent's discussion of the Carter Patent in suit (Brief pp. 12-18).

We first note that respondent admits (p. 13) that the radiation phenomenon, with which the patent in suit is concerned, had been known since Abraham's articles of 1898 and 1901. However, respondent makes the erroneous assertion that in the Abraham articles "the wire is assumed to be 'in free space'." The implication is that because Abraham's work was entirely without reference to ground effect, Carter may have really done something worth while in applying Abraham's formula to ground conditions. Truly, respondent's memory was short in making this assertion. In the I.R.E. article (Vol. II, p. 559) Carter and his co-authors made the statement that in the Abraham article:

> "*Abraham has treated the case of a grounded wire* • • •. Although the case of a wire free in space is similar in many respects to the cases already treated, it will nevertheless be analyzed in detail here."

Thus, though respondent's brief asserts Abraham discussed only a wire "in free space", Carter, in his I.R.E.

article, asserted that Abraham discussed only a grounded wire. The truth is that Abraham considered *both* conditions; in his 1898 article a wire in free space, and in his 1901 and 1904 articles a grounded wire.

Respondent next (Brief, p. 14) directs attention to:

> *"The first of the antennas of the Carter patent,* the one shown in Figure 2b • • •."

We ask the Court to compare this "Carter antenna" with the antenna of the prior Lindenblad patent (Vol. II, p. 486, Figs. 1 and 2). One of the questions this Court will be asked to decide is in what respect do the two differ? Respondent's brief suggests that the Carter antenna

> "is a very simple structure, consisting of two wires, A and B, which in practice may be strung on telegraph poles 80 feet high (patent, p. 3, line 58, II, 501) and are connected by the wires 10 with the source of energy at the radio station."

Obviously the same is true, in every respect, of the Lindenblad V-antenna.

Respondent next discusses the drawings of the Carter patent. Figs. 1a and 1b represent prior practice, and it is stated (Brief, p. 15) that Fig. 4 contains a feature *"which is not used by petitioner"*. Also it is stated (on p. 17):

> "The remaining figures of the patent, except Fig. 12 (which is merely a graphical representation of the Abraham formula), relate to refinements which are not here involved; we see no need to discuss them." (Matter in parentheses ours.)

Thus, the only antenna *structure* disclosed by the Carter patent which petitioner is charged with having appropriated is illustrated by Figs. 2a, 2b, and 2c. These figures differ from each other only in the manner in which the

transmission lines are connected to the antenna wires—a subject matter which was originally involved in suit with respect to patents not now remaining in the case, and with which claims 15 and 16 are in no way concerned. Therefore, these figures are materially the same as Figs. 1 and 2 of Lindenblad.

Finally, respondent's brief (pp. 17-18) makes the assertion that the Carter patent teaches the *optimum relation* of the angle between the wires, the lengths of the wires, and the wave length employed *for all finite lengths of wire.* This, of course, is not so, as we have pointed out in our main brief (pp. 19-21). But even if it were true, it would merely mean that although the Abraham formula can be correctly applied to wires an integral number of half wave lengths long, Carter used it for all *other* lengths, ignoring the errors that result from so doing. Can it be seriously or successfully contended that this amounts to an *invention?*

Respondent's discussion of Petitioner's Antennas (Brief pp. 18-21).

While we have in our main brief, and elsewhere in this reply, explained in what respects petitioner's antennas differ from the Carter patent, one further remark is in point.

Figs. 1a and 1b of the Carter patent (Vol. II, p. 492) give the radiation pattern of the prior antennas. The significant fact is that the four main lobes of radiation *are at an angle to the plane of the wire.* Fig. 3 of the Carter patent (p. 494) illustrates the radiation pattern obtained by the Carter invention. Here it will be seen that the main lobes of radiation are *not* at an angle to the wire. To the contrary, they are geometrically con-

fined to the plane of the wires. This is consistent with the many statements in the patent, and with the testimony of respondent's expert that the invention of the Carter patent contemplated radiation *confined to the plane of the wires and on the bisector of the V.*

Let us next see, therefore, what is the radiation pattern of the prior Lindenblad V-antenna patent. Exhibits CC and DD (Vol. II, pp. 897-898) are such patterns, and are conceded to be correct by respondent (Brief p. 48). In these patterns the main lobes of radiation are *not* in the plane of the wires along the axis of the V, but, to the contrary, are at *a substantial angle* thereto. In this respect only do the patterns of the Lindenblad and Carter antennas differ. The main lobes of the radiation patterns of petitioner's antennas (Exhibits S and T, Vol. II, pp. 745-746) form substantially the same angles with the wires as in the Lindenblad antenna.

With these facts in mind, we direct the Court's attention to page 48 of respondent's brief where it is stated that Carter obtained *a new result,* as compared to what Lindenblad obtained; and that this new result was exemplified by the difference in the radiation patterns of the Lindenblad and Carter antennas. Obviously, therefore, Carter differs from Lindenblad *only* in the same respect that petitioner differs from Carter.

Respondent's treatment of infringement (Brief pp. 23-35).

Respondent's discussion of this subject starts with an attempt to attach some importance to the fact that petitioner strings its antenna wires on poles 80 feet high, and that poles of that height were recommended in the Carter patent. Here, again, is an implication that petitioner

copied something from Carter. Such an implication is wholly unwarranted. Carter himself admitted (Vol. I, p. 430, fol. 602) that—

> "The antennae were constructed on 80 foot poles. They were the standard size poles obtainable; we had a large number of those poles at Rocky Point; we had been using them before that. They are the standard size for telegraph poles. I believe you are right in stating that the longer-sized poles come from the West Coast; for that reason an 80 foot pole is what is ordinarily used here in the East, because of the expense incident to getting taller poles."

Naturally petitioner used the only available poles which were "standard-sized for telegraph poles 'which were' ordinarily used here in the East". Moreover, it should be noted that petitioner's antennas were constructed prior to the issuance of the Carter patent.

In the next paragraph (on p. 23 of its brief) respondent quotes from our main brief to the effect that the present litigation has to do solely with antenna structure (as distinguished from theory of operation). With this as a foundation, respondent argues that it is conceded by petitioner that the Carter patent is for a *structure.* Of course, no such concession has ever been made, and it is not the fact. The Carter patent is solely for a theoretical determination of an angle between the legs of a V-antenna in which radiation is confined to the plane of the wires along the bisector of the angle, and the *only* invention claimed by the two claims in suit is *a mathematical formula by which that angle can be determined.* There are numerous claims of the Carter patent which *are* directed

to *structure* (*e. g.* claims 36-41) which were originally charged to be infringed. As to those claims respondent has acquiesced in the decree of the District Court that petitioner's antennas do not infringe.

On page 26 of its brief respondent contends that the repeated references in the patent to radiation in the plane of the wires and on the bisector of the angle mean radiation *"in compass directions"*. This is not what the patent says, and respondent advances no justification for thus misreading the patent.

Again, respondent seeks to avoid the consequence of the fact that petitioner's antennas radiate at *a substantial angle to* the plane of the wires, as distinguished from radiating *in* the plane of the wires, by saying that this happens in Carter also as "unavoidable effects of the presence of ground"—*"at a distance from the antenna"*. The fallacy of this contention is that it is flatly contradicted by the patent itself. Figs. 6 and 7 of the patent are *power distribution* curves, and show precisely what happens *at all distances* (see specification p. 499, lines 89-93). These drawings illustrate that at *all* times, and at *all* distances *the radiation is confined to the plane of the wires and along the bisector of the angle between them* (see, also, respondent's brief, p. 15; and Hogan's testimony, Vol. I, p. 125, and p. 128, Q78 *et seq.*).

On pages 27 and 29 respondent attempts to excuse Carter for his failure to mention the "well known and inevitable effects of ground" by stating that "Carter did not think it necessary to analyze or describe" these effects. Obviously, neither this excuse nor this explanation is sufficient. Carter either did or he did not know of the effects of ground. We, of course, believe that he

did, for he was concededly an expert in his art. If we are correct in this belief, it is inconceivable that he would have subscribed to a patent specification and claim as his invention something not only wholly inconsistent with but contrary to ground effect, unless he believed that he had invented means to *avoid* ground effect. That, in the final analysis, is what the Carter patent is directed to, namely, *means for avoiding ground effect.* Indeed, it is only by this avoidance of ground effect, *whereby predominant radiation is maintained in the plane of the wires and concentrated along the bisector,* that Carter claimed any difference in function from the prior Lindenblad V-antenna patent, according to respondent's own assertion (Brief p. 48).

Under these circumstances, the authorities cited by respondent (Brief pp. 29, 31) are not in point.

It is true, as respondent states (Brief p. 33), that the Abraham formulas are correctly applicable only to wires an integral number of half wave lengths long, and it is here that respondent, *in italics,* heralds Carter's contribution of the empirical formula as something which gives "by direct solution, the desired angle and gives it *not only for the limited condition to which the Abraham formulas are applicable* (integral half wave length wires) but also for *all other wire lengths*". As we have already pointed out and here repeat, *this is refuted by the patent itself,* and illustrates the fundamental fallacy of respondent's theory of the Carter patent. It is a matter of simple logic that if the *exact* formula will not apply to wire lengths other than an integral number of half wave lengths, surely an *empirical* statement of the formula could not do so.

Respondent's contentions as to the rule of *Adamson* v. *Gilliland* (Brief pp. 35-37).

Respondent attempts to avoid the effect of the rule by asserting that the findings of the District Court were *"all"* merely *"interpretation of written documents"*; that the District Court erroneously interpreted the documents and was corrected by the Court of Appeals.

It is significant that respondent does not question the fact that there *was* "testimony consistent with the finding" made by the District Court, which fact alone, under the rule, made the finding "unassailable".

However, as a matter of fact, there is no justification for respondent's assertion. In arriving at his conclusions in this case it was necessary for the District Judge to make findings on the structure and operation of petitioner's antenna; the technical or scientific differences between the disclosure of the Carter patent and the patents of the prior art; the correctness or incorrectness of the applicability of the Abraham formula (or its empirical restatement by Carter) to wire lengths other than those an integral number of half wave lengths long; the technical and scientific effect of Carter's amendment to his specification in his eleventh-hour attempt to include petitioner's antennas; and the scientific effect of whether or not an antenna system which confined its radiation to within the plane of the antenna wire was practical, useful or had ever been commercially utilized. Clearly, none of the District Court's findings on these controlling matters was based or could have been based solely on "interpretation of documents". These were all findings of fact, and it would have been impossible for the Court to have disposed of the case without making them.

Therefore, if the rule of *Adamson* v. *Gilliland* is not applicable to the present case, it is difficult to conceive of a case to which it would be applicable because, in all patent infringement cases, the issues decided by the Court are validity and infringement, which always require the construction of printed patents, publications or other patent documents.

Respondent's discussion of Carter's unlawful expansion of his application (Brief pp. 37-41).

As pointed out in our main brief, pages 38, 39, the Carter application as filed and the patent as issued are expressly directed to a *standing* wave antenna system. This was one of the respects in which Carter sought to differentiate from the disclosure of Figures 3 and 5 of the prior Lindenblad V antenna patent, which figures showed a *traveling* wave system. (Figs. 1 and 2 of that patent show *standing* wave antennas.)

As there pointed out, as well as in footnote 8 of respondent's brief, page 12, the wires of a *traveling* wave antenna are, in electrical parlance, of *infinite* length. As distinguished from this, the wires of a *standing* wave antenna are electrically of *finite* length.

Thus, when Carter filed his application for patent, he used the word "finite" to emphasize that *his* antenna was of the *standing* wave type. He did not and could not have used it in any other sense because a *physically* infinite wire would be an impossibility. Respondent's contention that this word as thus used by Carter meant wires of *any* length is belied by the context in which it is used. Thus, in the first paragraph extracted by respondent from the Carter application, it is expressly stated that the object

of Carter's invention was to disclose the proper angle for conductors "either an even number of half wave lengths long or an odd number of half wave lengths long", and then, *to emphasize the fact that his invention was confined to a standing wave antenna,* he proceeded to say "and, in general to disclose the angle for best directional propagation for wires of any *finite* length". This could mean only wires an even or an odd number of half wave lengths long that are *electrically finite,* as distinguished from *electrically infinite.* If Carter really meant *every* wire length, as respondent contends, why did he so meticulously refer in the same sentence to the number of odd and even half wave lengths?

It is obvious that Carter contemplated any standing wave antenna, regardless of the length of the wires, *provided they were an even or an odd number of half wave lengths long;* in other words, wires *electrically* finite in order to be a *standing* wave antenna, *and* of the integral number of half wave lengths in order to enable the Abraham formula to determine the correct angle.

As contrasted with this, the corresponding paragraph of the patent, after the illegal amendment thereof, *has had deleted therefrom this controlling language,* so that the patent now states that the invention is directed to *all lengths of antenna wires in a standing wave system.*

In view of the foregoing, it will be apparent that the remainder of the quotation from the Carter application (Brief, p. 39), where it refers to wires "of any length whatsoever", merely means wires an integral number of half wave lengths long, regardless of how many half wave lengths are employed. This is emphasized by the fact that in connection with that statement the application as filed

expressly stated that the law giving the correct angle for lengths *between* odd and even number of half lengths *is not given "due to its complexity"*.

In conclusion on this subject, we point out that the only passage of the patent which definitely asserts that wire lengths *between* half wave lengths are included within the patent is the paragraph contained between lines 35 and 43, page 4 of the patent (quoted in footnote 19, page 19 of our main brief). *This is nowhere denied by respondent.* But this entire paragraph was inserted in the application after the filing of the original bill of complaint in this case. The language of this paragraph is simple. Carter found no difficulty in expressing its thought *after* he was aware of the desirability or necessity of doing so, although, as is revealed by the file wrapper, he had considerable difficulty in convincing the Patent Office Examiner of the propriety of such expansion (see Vol. II, p. 1121).

Under these circumstances, it is pure sophistry on the part of respondent to assert, as it does in italics (Brief, page 40), that if the patent had issued *exactly as filed,* it would have described and claimed petitioner's antenna. If this were true, there would have been no necessity for amending the Carter application after its allowance, and after respondent had become familiar with petitioner's antennas. It is significant, therefore, that respondent offers no explanation why this occurred.

Respondent's consideration of the prior art (Brief pp. 41-49).

In its discussion of the Abraham articles respondent advances as one of its varying definitions of the Carter invention the empirical formula which is stated to be applicable whether or not the length of the an-

tenna wire is made up of an exact multiple of half wave lengths, whereas the Abraham formula would correctly apply *only* to wires of that exact length. If this, in fact, constitutes Carter's sole contribution to the art, it certainly is not what is advanced by the patent, and it certainly constitutes no invention.

If the *correct* formula is inapplicable to wires other than those an exact multiple of half wave lengths, certainly the *empirical* statement of that formula could not apply any better. Moreover, the Carter patent states on its face that it does *not* purport to give the formula for wires of lengths between integral numbers of half wave lengths "due to its complexity"; and it is significant that throughout his patent Carter claims the Abraham formula in its original as well as in its empirical form *as meaning the same thing.* As Kelley demonstrated by means of Exhibit W (Vol. II, p. 820), for all practical wire lengths, and certainly all those with which this case is concerned, Fig. 12 of the Carter patent would be the same whether the Abraham formula or the empirical formula was used to plot the curve.

Finally, we ask the Court to compare the claim *here* made by respondent's brief for the Carter patent with the statement at page 53 thereof that "Carter did not patent or attempt to patent any formula"; he "merely utilized the Abraham formulas in mathematically analyzing and explaining a theory of results he got from his new structure."

Respondent seeks to avoid the anticipating effect of the French Bethenod and Levy patents with the statement (Brief pp. 44, 45) that they show *networks,* and hence are not relevant to the Carter patent. That this is no distinction is evident from the fact that the Carter patent discloses similar networks when illustrating the preferred forms of his alleged invention (see Figs. 4 to 11, Vol. II, p. 494).

Respondent also says that the Bethenod patent fails to disclose the Carter invention because he does not disclose "long" wires. That is not true. Bethenod employed wires as long as Carter. Respondent itself points out (Brief p. 43) that the Bethenod patent—

> "discloses an admittedly old type of long wave antenna".

Long wave antennas (as made apparent from respondent's footnote 7, p. 12) were all electrically *long* as compared to short waves.

Thus, in the only two respects that respondent seeks to differentiate Carter from the prior art, no differentiation in fact exists.

As to the second Bethenod patent (Brief p. 44) respondent conveniently omits all reference to the ground effect, just as the Carter patent does. If the Carter patent can be construed to cover an antenna system which operates *because* of ground effect, then this Bethenod patent becomes a complete anticipation because the ground constitutes the other antenna wire.

Respondent's consideration of the prior Lindenblad V-Antenna Patent (Brief pp. 46-49).

While this subject has been heretofore covered in considerable detail (*ante*, pp. 5, 7, 9), we wish briefly to refer to respondent's argument made on these pages.

Respondent asserts that

> "Lindenblad did not consider the angle between the wires to be of importance".

and that Lindenblad recommended

> "an angle of about 12°, regardless of wire length and wave length" (Brief p. 47)

which respondent exaggerates into a *fixed*

"half angle of just under 6°" (footnote 27, p. 34).

This is untrue in its entirety. The Lindenblad patent is *not* for a *fixed* angle, nor does it recommend, with respect to its *standing* wave antenna disclosure, *any* angle other than what may be desired to be used between 0° and 180° to obtain radiation in the plane of the wires along the axis of the V, just as in Carter.

The only support for its erroneous assertions that respondent finds is quoted on page 47 of its brief. This quotation is advanced as the *beginning of a sentence* allegedly appearing at lines 115 to 119 on page 2 of the patent (Vol. II, p. 488). This is a misrepresentation. *What is quoted is extracted from the middle of a sentence.* The *whole* sentence does not support the assertions. The entire quotation is as follows:

> "*Since the preferred radiation is from the travelling wave, and is due to the expansion of the lines of force between the current charges travelling along the conductors,* the divergence should preferably be fairly gradual, and the spacing at the open end, while variable over a great range, should be in the neighborhood of a fifth of the length, *and the length of each antenna section should be of the order of magnitude of five to ten waves long.*"

For the convenience of the Court we have emphasized the portions of the sentence *which respondent ignored and failed to reproduce.* Thus, reading the entire sentence, it will be seen that the first part thereof which respondent omitted, shows that Lindenblad was referring exclusively to the *travelling* wave antenna structures of his Figs. 3 and 5, as to which the entire sentence would be correct; and that

it had nothing whatever to do with the *standing* wave structure—viz: the structures of his Figs. 1 and 2 with which alone we are here concerned—as to which both the entire sentence *and* the portion thereof quoted by respondent, would be wholly incorrect. Moreover, the last part of the sentence which respondent omits from its quotation, makes it quite evident that Lindenblad realized the necessity of correlation between angle and wire length, whereas respondent's mere assertion that Lindenblad had no such knowledge is the sole reason advanced by respondent why Lindenblad was not a complete anticipation of Carter (see, for instance, respondent's brief, p. 32).

It is true, as respondent comments (Brief p. 48), that the Carter patent was allowed over the Lindenblad patent which was cited by the Patent Office Examiner, but respondent fails to point out that this allowance was secured only by insisting that Carter supplied the *exact* angle, whereas Lindenblad did not. By the present suit respondent seeks to cover antennas which do *not* use the "exact" angle, and has induced the Court of Appeals below to construe the Carter patent as covering a *range* of angles. Neither the specifications nor the claims give any indication of what this *range* should be. The Lindenblad patent was advanced to the Patent Office, and to the Courts below in the present case, as covering *all* angles from 0° to 180°. Thus, in the prosecution of the Lindenblad patent, as will be seen from its file wrapper (Vol. II, p. 1002), it was stated—

> "The present invention is not limited in scope to any gradual divergence or convergence since it covers a wide range of departure from the parallel condition of two straight wires, *this range extending up to, but not including the well known 180 degree spaced dipole antenna.*"

Therefore, if the Carter patent covers a *range* of angles, as respondent now asserts, and as was held by the Court of Appeals below in order to make petitioner's antennas infringements, the patent is fatally defective for want of sufficient disclosure, and for want of sufficient definition and limitation of its claims. In *General Electric Company* v. *Wabash Appliance Corporation*, 304 U. S. 364, this Court held the Pacz patent invalid, *inter alia*, because the specifications and claims failed to define the necessary size of tungsten grains so as to set forth the limits of the monopoly as required by the Statute. Here the situation is even worse. The Carter patent *does* specify that the advance made over Lindenblad is the determination of a *precise* angle, and respondent is seeking to expand the monopoly granted for that *precise* angle determination so as to cover a *range* of angles of which neither the upper nor the lower limit is stated in the patent, nor by the Court of Appeals below, nor by counsel for respondent, nor by anyone else.

Another flagrant misuse of the evidence is contained in footnote 38 of respondent's brief (p. 48). Petitioner's expert was testifying in connection with Exhibits CC and DD (Vol. II, pp. 897, 898), which apply to the Lindenblad patent. That patent was advanced by respondent as covering a V-antenna, regardless of the angle. Defendant proved that not *all* of the angles between 0° and 180° would result in predominant radiation along the axis of the V, and that, therefore, the Lindenblad patent was invalid as too broadly claimed, V-antennas being old in Bethenod, Levy, etc. Exhibits CC and DD were instances, mathematically evolved and not questioned as to accuracy, of *particular angles* where predominant radiation would *not* be effected along the axis; and Kelley's testimony, quoted in respondent's footnote, is with respect to those two instances. Now, how-

ever, respondent quotes Kelley's testimony in support of an argument, the implication of which is that *all* radiation effected with the Lindenblad V-antenna is at an angle to the axis of the V, and that it is in *this* respect that Carter differs from Lindenblad.

Respondent's treatment of the prior work of Bruce (Brief pp. 49-51).

Contrary to respondent's remarks, petitioner has not "abandoned" Bruce as a prior inventor. In the trial of the case the Bruce evidence was of particular importance because petitioner was charged with infringement of *seventeen* claims of the Carter patent, and the evidence of Bruce's prior work was an important factor in leading the District Judge to the correct conclusion that none of these claims was infringed by petitioner's antennas. By respondent's acquiescence in the decree of the District Court as to *fifteen* of these claims, we are now concerned only with claims 15 and 16, the sole "inventive" feature of which is Carter's empirical statement of the Abraham formula. It was not considered necessary, therefore, to mention Bruce's work in our petition for a writ of certiorari. In accordance with this Court's decision in *General Talking Pictures Corp.* v. *Western Electric Co., et al.*, 304 U. S. 175, in addition to regarding it as unnecessary, we considered a detailed discussion of the Bruce evidence improper.

However, since respondent goes into the subject, we must point out that on September 28, 1926—*four years prior to the application for the Carter patent in suit*, and within a few months after Bruce started his investigations (in May, 1926)—he plotted out what we may term a "rule-of-thumb" application of the Abraham formula as applied

to V-antennas (Exhibit JJ, Vol. II, p. 902) which, as Kelley demonstrated (by Exhibit W, p. 820), meant the same thing as Fig. 12 of the Carter patent. It was on the strength of this that the District Court found, quite correctly, that petitioner's antennas differed from Carter to as great an extent as Carter differed from Bruce. Therefore, under an elementary rule of law, if petitioner's antennas infringe the Carter patent then, inevitably, Bruce anticipates.

Respondent's treatment of "specific matters" in petitioner's brief (pp. 51 *et seq.*).

Under this heading respondent discusses ten enumerated points. Our reply, for ready identification, will be identified by the same numerals.

(1) Respondent endeavors to escape the significance of the statement in the Carter patent that when it is *desired* to radiate *at an angle to the horizontal plane of the wires,* it is necessary to tilt the wires from their horizontal position to the required angle so that the wires will be tilted in the direction of desired radiation, because the Carter antenna always confines its radiation to the plane of the wires. However respondent insists—

"This is *not* what the patent says" (emphasis respondent's) and, further, that the patent merely says to tilt the antenna—

> "*towards* the *direction* in which the beam of energy is to be propagated".

There is thus raised a simple issue of fact. Let us see, therefore, just what Carter claims by his patent with respect to this feature.

We direct the Court's attention to claims 26, 27 and 29 in which it will be seen that Carter expressly *claims* as his

invention the feature that when radiation is desired at an angle to the horizontal, the wires must be

> "placed in a plane at an angle to the horizontal, said plane extending *in* the direction of transmission."

(2) Here respondent endeavors to avoid the effect of Carter's admission in his subsequent patent that the patent in suit, by its very subject matter and alleged invention, intentionally disregarded ground and sought to avoid the effects thereof. That is the point we made in our main brief, and respondent avoids meeting it in any respect.

(3) It is here that respondent asserts that what Carter invented was an antenna and not a formula. We have covered this matter fully earlier in our reply (*ante,* pp. 2, 3, 7).

(4) Respondent in this paragraph misstates our position. We at no time have stated, or here state, that Carter's empirical formula is *wrong.* All we say, and it cannot be successfully denied, is that the empirical formula can have no greater accuracy as applicable to any physical conditions than can the original formula from which it was derived. Indeed, as we have shown (*ante,* p. 17) Carter's empirical statement of Abraham's formula is identical with the Abraham formula when applied to all wire lengths with which this litigation is concerned.

(5) Here respondent asserts that petitioner's antennas are not the old V-type antenna structures, assertedly because no prior art shows a single description of a V-antenna employing the coordination of elements taught by Carter. This is amazing. We assume that what respondent refers to is the exact angle for a V-antenna structure formed of wires an integral number of half wave lengths long determined by the Abraham formula. The prior Lindenblad V-antenna

patent discloses all of these elements in this identical "co-ordination", unless there is legal justification for Carter to assert that by his utilizing an *exact angle* somewhere between 0° and 180°, he is different from Lindenblad. If that difference entitles Carter to a valid patent, and we submit that it does not, then petitioner does not infringe because, concededly, none of its antennas employs that *exact* angle for the antenna wire length utilized. If the Lindenblad patent covers all angles from 0° to 180°, how can Carter validly monopolize any angle or range of angles that is determined by the simple application of a scientific formula which was published thirty years before for the express purpose of determining *any* desired angle? These questions are particularly pertinent in the present case where no limits for the range are given or even suggested.

(6) Kelley, on direct examination, stated that petitioner's antennas were "intentionally" and "deliberately" designed so as to radiate at an angle to the plane of the wires as distinguished from Carter's radiation in the plane of the wires. Clearly, with knowledge of the structure and functioning of the antennas, and of the far more efficient results obtained thereby, any expert in this art would know that such functioning was deliberate and intentional, and this is precisely what Kelley testified to in the very passages of his testimony from which respondent has again extracted one short statement, and has ignored the remainder which completely refutes the purpose for which respondent uses the short statement (see Vol. I, p. 269, XQ-1063 to XQ-1088).

(7) In this paragraph respondent denies our assertion that the Carter patent is a "paper patent", as we have amply demonstrated and as the District Court found. It is only the Carter invention exemplified in Figs. 2a, 2b

and 2c that petitioner is charged with having appropriated; *and there is not one word of evidence in the case that respondent has ever constructed or commercially utilized an antenna in accordance with any of these figures.*

(8) On reaching the present stage of its brief, and realizing that in the preceding pages it has discussed the conflicting testimony on which the "findings" of the District Court were based, respondent makes the assertion that the "findings" of the Trial Court were "chiefly" interpretations of written documents, and denies the applicability of the rule of *Adamson* v. *Gilliland.*

(9) To determine the number of witnesses who testified in the case it is merely necessary for the Court to refer to the index of Volume I of the record.

(10) In this concluding paragraph respondent admits that the "reflector effect", which alone distinguishes claim 16 of the Carter patent from claim 15 thereof, was known many years prior to Carter. With this admission we have nothing to add to our discussion of this subject and the applicable authorities given in our main brief (p. 42).

Conclusion.

The Carter patent is neither valid nor infringed, wherefore the decree of the Court below should be reversed as to the Carter patent.

Respectfully submitted,

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IN THE

Supreme Court of the United States

October Term, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

vs.

RADIO CORPORATION OF AMERICA,
Respondent.

Respondent's Petition For Rehearing

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IN THE

Supreme Court of the United States

No. 127 October Term 1938

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
Petitioner,

v.

RADIO CORPORATION OF AMERICA,
Respondent.

PETITION FOR REHEARING

Now comes the respondent, and petitions the Court for a rehearing for the following reasons:

1. *The opinion shows that the Court has disregarded portions of the record which negative its conclusion that the claims and disclosure of the patent in suit were improperly expanded by amendment.*

This Court has held that the disclosure of the application for the patent in suit was amended—

> "After *** respondent *** had acquired knowledge of the particulars of the structure and operation of petitioner's antennae"—

to expand the disclosure and claims to include petitioner's antennae, and that petitioner's antennae were not within the original disclosure. This holding ignores the *plain* language of the application *as filed*. It is contrary to the evidence. The uncon-

tradictable fact is that no amendment was made, either before or after the struct re of petitioner's antennae became known, that in the slightest degree expanded the scope of the claims in suit, or altered in any way the meaning of the disclosure upon which the claims in suit are based.

The antenna structures subsequently erected by petitioner were both described and claimed in Carter's application as filed (II, 1038, last paragraph; II, 1047, original claims 19 and 20). **Claim 16 (here in suit; original claim 20) was not amended in any way whatsoever after September, 1931,—which was eight months before petitioner built its antennae.** The necessary effect of this Court's opinion is that Carter's application did not mean what it said; yet there is no other meaning that can be given to this portion of the application and this Court has not suggested that there is. This Court has in effect **erased** from the specification an important part thereof, thereby doing a grave injustice to the patentee. *In fact, this Court has interpreted Carter's application in the very way that the preliminary draft of the application was modified, before filing, to prevent.*

2. *The opinion says that defendant's structures utilize angles that "differ from the angles of the formula" of the claims in suit, and the Court has found non-infringement for that reason, inter alia.*

This ignores the undisputed facts (1) that petitioner's antennae secure the result described by Carter,— *i.e.*, predominant radiation in the direction of the bisector of the angle between the antenna

wires,—a result not attained with any prior art V-antenna; (2) that *nine out of eleven* of the accused antennae depart from the angle of the empirical formula of the claims in suit by *less than one-half degree* (½°); (3) that one of them has an angle only two one-hundredths of a degree (.02°) *less* than that called for by Carter's empirical formula, and that another has an angle only seven one-hundredths of a degree (.07°) *greater* than the angle called for by Carter's empirical formula; (4) that the angles of three of defendant's eleven antennas are admitted by defendant's expert to be "as close as you can determine on that curve" to the angles called for by Fig. 12 of the patent (I, p. 309, XQ. 1398-1400); and that only one of petitioner's antennas departs from the angle specified by Carter by as much as two and one-half degrees (2½°); and (5) that the claims in suit call only for "substantially" the angle there set forth. A windstorm causing a pole to lean could easily make a change of angle greater than that which this court has treated as taking petitioner's antennae outside the scope of the claims.

3. *The Court has treated the mathematics, used in the patent specification to explain a theory of functioning of certain special wire lengths of a V-antenna, as though that explanation were itself the invention. It has limited the scope of the patent to the special cases for which the mathematical explanation was set forth. It has ignored the plain disclosure of the application as filed which specifically pointed out that ANY wire lengths could be used, provided the proper angle was chosen. It has ignored the fact that the application gave a formula and curve which was stated to be (and is)*

"sufficiently accurate" "for all practical purposes" for determining the proper angle for wires of any length.

The opinion gives no weight to the fact that the patent is on a simple structural arrangement, the essential factor being properly to *correlate* the elements. The empirical formula of the claims in suit and Fig. 12 of the patent, both contained in the application *as filed,* and unchanged in any respect whatever by amendment, complied with all of the statutory requirements of disclosure. They taught with certainty how to correlate the elements of the patented antenna, regardless of wire lengths used, to secure all the desired results. There can be no dispute on this point. Petitioner uses substantially the angles indicated by the curve and given by the formula and gets all the results taught by the patent.

4. *The Court holds (opinion, page 8, second paragraph) that the claims do not apply to wire lengths not multiples of integral half wave lengths*

> "both [1] because such structures are not within the invention described in the application and [2] because structures having wires of that length do not in fact exhibit 'the angle for the best directional propagation.' "

Both of these statements of the Court are entirely incorrect, and without support in the record. They constitute controlling errors in arriving at the holding of non-infringement. This is pointed out in detail in our brief herewith.

5. *The opinion ignores outstanding equities based on undisputed facts.*

(a) Carter produced a highly directive antenna of simple structure, having advantages over anything known in the prior art. He did this by means not apparent to or discovered by any of the many skilled engineers shown by the record to have been working intensively for several years on this same problem. This research was not only in the United States, but in England, France, and Germany also.

(b) Petitioner built its antennae *in exact accord* with detailed descriptions of respondent's commercial antennae previously published by Carter, *et al.*, in the Proceedings of the Institute of Radio Engineers, and after respondent's commercial antennae had fully demonstrated the truly startling efficiency and economy of the Carter antenna. Petitioner has made no claim whatever to any originality or independent research in this subject matter. It obtained the benefit of respondent's years of research by a direct copying of respondent's V-antenna structures, even to the odd quarter wave length wires which this Court has regarded as a distinguishing difference.

6. *The Court has erred in holding that the invention was a narrow one and should be narrowly construed.*

Although the opinion shows that this Court realized that various forms of directive antennas were old in the prior art, and that there had been much unfruitful effort, it has regarded as a narrow invention a structure that greatly improved on all prior art antennas.

While admittedly the change of form was simple, the result was to increase the effective directivity of

the old V-antenna (that of the second Lindenblad patent) many-fold. The increase in concentration of energy was far beyond what could have been predicted. What now seems simple to the Court was not apparent to many skilled scientists and research workers in this art, (many of whom are shown by this record to have been familiar with the Abraham formulae), during many years of work on short wave directive antenna development.

This Court has reversed the Court below upon grounds which, aside from the clear errors of fact upon which they are based, are purely academic, or technical. It has apparently given no weight to the evidence of substantial and practical achievement. It has considered the mathematics of a theory of operation, and has ignored the substance of a very practical and useful invention. The establishment of such a rigid and technical point of view by this Court in considering the validity and scope of a patent having such an undisputed record of substantial achievement and effect on its art, would indeed be a sad day for the patent system in this country.

Certificate of Counsel

We hereby certify that the foregoing petition for rehearing is presented in good faith and not for delay.

Respectfully submitted,

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BRIEF IN SUPPORT OF PETITION FOR REHEARING

1. The Court Has Held That There Was Improper Amendment Broadening The Original Disclosure and The Claims in Suit

That the Court has regarded the alleged improper expansion of the disclosure and claims as a fundamental factor in its limitation of the patent to a scope not including petitioner's antennae, appears throughout the opinion, as we understand it. For example, on page 1, second paragraph, it says*:

> "After petitioner had answered and respondent, *as a result of the litigation*, had acquired knowledge of the particulars of the structure and operation of petitioner's antennae, Carter, respondent's assignor, *amended the statement of his invention in his application so as in terms to embrace a differentiating feature of petitioner's structure.*"

At the top of page 2, the opinion quotes with approval the statement of the Trial Court that

> "*The disclosure and the claims were broadened not only contrary to their original terminology, but to their spirit as well.* *** by those amendments the plaintiff attempted to mold the third Carter patent both as to disclosure and claims, *to cover defendant's antenna systems.* This could not lawfully be done."

On page 8, in the second paragraph, the opinion says:

> "we are not able to construe the application, *before amendment at least*, as embracing such an extension. And we think that *the attempt to extend the claims*, based on the application of the empirical formula, to

*Emphasis in quotations ours.

wire lengths not multiples of half wave lengths, must fail, both *because such structures are not within the invention described in the application****."

In the first paragraph on page 9 the opinion says that the claimed use of the empirical formula

> "thus *involved a departure from what Carter's application had described as his invention, and a contradiction of it.*"

In the next paragraph the opinion refers to—

> "This *attempt to broaden the only invention described in the application****."

These, and other statements in the opinion, as we understand it, refer to the erroneous belief that Carter's application *as filed* was limited in its disclosure and usefulness to antennas which *necessarily* comprised radiator wires made up of half wave lengths, and did *not* disclose or teach how to construct an antenna with wires of any intermediate lengths, and particularly that Carter's original teaching was not applicable to antenna wires made up of an odd number of quarter wave lengths, as are most of petitioner's structures.

The Court's position, as we understand it, is further that Carter's invention was based *solely* on applying to a V-antenna the mathematics derived by Abraham; and that since the Abraham mathematics dealt only with a single wire an integral number of half wave lengths long, therefore the Carter invention could not be applicable to wires not likewise an integral number of half wave lengths long, because he disclosed no mathematical determination of angles for such intermediate lengths.

The Original Disclosure Was Applicable To Wires Of Any Length And It Was Not Expanded By Amendment

With all due respect for this Court's opinion to the contrary, we assert that the documentary evidence shows beyond the possibility of doubt that Carter's application *as filed* disclosed and claimed and gave complete instructions for coordinating the elements of V-antennae having wire lengths *not* composed of integral half wave lengths (*e.g.*, odd numbers of quarter wave lengths as used by petitioner).

We shall here trace the matter in some detail, in spite of its tediousness, because it is vital to this case, and vital to prevent this Court from standing on a decision based on an utterly false premise.*

The Carter application *as filed* in 1930, (two years before petitioner's V-antennae were built), contained the following specific statement to the effect that the desired results could be obtained by using wire lengths *not* composed of integral half wave lengths.

> "Moreover it should be clearly understood that the wires of each unit can be of any length whatsoever provided they are placed at the correct angle for their length. For best tuning, the total over-all length of both of the wires and the 'U' loop terminating them should be effectively an integral number of half wave lengths, but, the portion forming the radiation element can be of any length. The law, giving the correct angle for lengths between odd and even number of half wave lengths, is not given due to its complexity, but the empirical formula and the

*In an appendix (pp. 29-35 below) we have treated the matter from a more technical viewpoint and have shown certain scientific misconceptions, evidenced by this Court's opinion, which appear to be at the foundation of its erroneous conclusions.

curve of Fig. 12 will be found accurate for all practical purposes, where the length of wire dealt with does **NOT** correspond to a whole number of half wave lengths." (II, page 1038)

This paragraph, without change in substance, appears in the *patent* at II, p. 501, lines 8-23. There is nothing whatever in any other part of the specification or subsequent history to negative the effect of the plain language used in that paragraph.

On page 6 of its opinion, this Court says that

> *Respondent insists* that *** [petitioner's antennae infringe] because, as *it argues*, the invention disclosed by Carter's application, *elaborated by amendment and broad claims*, embraces all V antennae arranged at an angle double the angle of the empirical formula, even though the length of the wires is not an exact multiple of half wave lengths, ***."

But respondent stands squarely on the Carter application *as filed*. It has not asked any construction based on any amendment to either specification or claims.

The statute* (Rev. Stat., sec. 4888) requires a description of the invention or discovery to be merely—

> "in such full, clear, concise, and exact terms *as to enable any person skilled in the art or science* to which it appertains, *** *to make, construct, compound, and use the same;* ***."

In his application, Carter described a V-antenna, specifically stated that "the radiation element can be of any length", and gave a formula (the empirical formula of the claims now in suit) and a curve (Fig. 12) for determining, with sufficient accuracy for all practical pur-

*Printed in full, last page of Appendix.

poses, the angle between the wires "where the length of wire dealt with does *not* correspond to a whole number of half wave lengths." Whether or not this formula was correct with mathematical precision, it was, just as he stated, "accurate for all practical purposes". It was sufficient to enable any person skilled in the art to erect and use the antenna and get the improved results disclosed. This has never been questioned by petitioner or its expert*. There is nothing in the record sustaining this Court's finding that the empirical formula and the curve of Fig. 12 of the patent "do not give the angle 'for the best directional propagation' for structures using this intermediate range of wire lengths". In fact, petitioner has demonstrated that the formula and curve are "accurate for all practical purposes" by constructing antennas utilizing angles 0.02° *smaller* and 0.07° *larger* than those of the formula and curve and securing the results described by Carter. (See pp. 16-18 below.)

Lest this Court think that the intention to cover, in the patent, antenna wires not an integral number of half waves long resulted from knowledge that petitioner was using wires of such lengths, we call the Court's attention to the following matters in the record which show, in unanswerable form, that it was the intention (and the right based on accomplished discovery) of the inventor to cover such antennae *ab initio*.

(1). Respondent introduced evidence to carry Carter's date of invention ahead of a V-antenna developed in 1930 by Bruce, and set up as a prior invention. In doing so the correspondence and test reports leading

*The most that Kelley, petitioner's expert, ever said was that the empirical formula did not give the "exact" angle and he would not say that it was wrong by as much as one-tenth of a degree (I, p. 238, 315). See the discussion of his testimony at pp. 34-35 below.

up to the filing of the Carter application were put in evidence. From these it appears that under date of May 14, 1930 (II, p. 667), Carter's attorney sent him "a rough draft of United States patent application papers covering your invention."

On May 20, 1930 (II, p. 692), Carter returned the first draft of the proposed patent application covering the invention here in suit, with certain penciled revisions noted thereon, and in an accompanying letter, *written to his attorney before the application was filed,* (and nearly two years before petitioner had any V-antenna) Carter said:

> "It appears to me that there are some statements in the specification which need a little clarifying. On page one one might gain the impression that it is essential for the proper working of this system that the length of the wires must be an integral number of half wavelengths. These wires can be any length whatever provided the angle is made correct to correspond. For the best tuning the total overall length of both the wires and the 'U' loop should be effectively an integral number of half wavelengths but the portion forming the radiation element can be of any length whatever. The law for determining the angle for lengths lying in between odd and even numbers of half waves was not given due to its complexity but the curves and the empirical formula give the correct values."

Thus, it is incontrovertible that Carter himself when returning the first preliminary draft of his specification saw that the first page of the specification might be construed as indicating that the antenna wires *must* be multiples of integral half wave lengths, to secure the desired concentration of radiation. Therefore, in order to prevent exactly the mistaken construction of his specification which this Court has made, he inserted in his original application the paragraph quoted at p. 9 above,

which is in almost the same words as his letter to his attorney.

(2). In this Carter was merely insisting upon a description of the invention that would **include an antenna that he had already built and tested.** The record shows (II, p. 699, 703, and p. 654) that Carter had erected and tested a V-antenna before filing his application, and had found it—

> "without doubt the simplest and cheapest of any system yet devised."

This antenna *had utilized antenna wire lengths that were not multiples of half wave lengths.* See II, p. 699, where at the middle of the page the Carter test report (made before application for the patent in suit) says:

> **"In the system tested the length [of antenna wires] was seven and three-quarter wave lengths."**

(3). Also, the I.R.E. paper published by Carter, *et al., eight months before petitioner built any of its V-antennas,* illustrates and describes (at II, p. 585) a V-antenna in which the radiating wires are 7¾ wave lengths long. *That is substantially the length of antenna wire used in several of defendant's antennas.* See Q. 452, I, p. 242, etc.

In view of such facts, can this Court possibly justify or leave of record its holding that Carter enlarged the scope of his application by amendments to sweep in a structure originating with Petitioner?

The Claims in Suit Were Not Expanded

The application as filed comprised claims 19 and 20 (II, p. 1047), which became claims 15 and 16 of the patent, the only claims now in suit. The original claims read as follows:

> **"19. An antenna comprising a pair of rela-**

tively long conductors disposed at an angle substantially equal to twice [formula identical with that of claims in suit omitted] degrees.

"20. An antenna comprising a pair of relatively long conductors disposed at an angle substantially equal to twice [formula identical with that of claims in suit omitted] degrees, and a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair along the bisector of the angle of the conductors."

In the first action (II, p. 1053) the Patent Office Examiner said:

"All the claims are rejected as incomplete since, 'angularly disposed' does not sufficiently define the structure. These claims should recite with respect to what the conductors are angularly disposed.

• • •

"In claims 13-22, inclusive, the definitions of the symbols used in the mathematical expressions should be included in the claims, in order to distinctly point out the invention."

Responding to these purely formal requirements, applicant's attorney (II, p. 1058) amended each of claims 19 and 20 by inserting "with respect to each other" after the word "disposed" in line 2; changing the period to a comma and adding at the end of each:

"*l* being the length of the wire and lambda the operating wave length in like units."

These amendments were made on September 4, 1931, *and the construction of petitioner's V-antennas was not even commenced until June of* 1932. *Claim* 20, *which issued in the patent as claim* 16, *was not thereafter amended in any respect whatever. It had taken final form*

before petitioner had any V-antenna. And yet this Court has been led to hold that claim 16 was broadened to include a distinguishing feature of petitioner's antenna!

Claim 19, which issued as claim 15 in suit, was further amended on May 4, 1934, by adding to it the following (II, p. 1098):

> "and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length."

This amendment brought no matter into the claim not fully disclosed in the original application, which at II, p. 1038, said:

> "It should be mentioned here that energy to the radiators A, B, should always be fed thereto out of phase***."

And claim 2 of the original application (II, p. 1043) contained the same elements now under discussion:

> "2. A directional transmitting antenna comprising a pair of angularly disposed linear conductors, each substantially ~~a~~ plurality of half wave lengths long and open-ended, and, *means for exciting the radiators in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the radiators.*"

The Trial Court was apparently adversely influenced by the fact that an amendment was made (II, p. 1123) adding the following paragraph to the specification:

> "By the term 'plurality of wave lengths,' or 'plurality of half wave lengths,' or 'several half wave lengths,' it is not intended that the wires so described shall necessarily be an exact or approxi-

mate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified."

That amendment, whether proper or improper, has no bearing upon the two claims here in suit, because they do not contain, and never did contain, any reference to half wave lengths as a limitation or measure of the length of the antenna wires. Aside from that, the application as a whole clearly justifies the amendment that was made, if that be important here.

2. Petitioner's Angles Are Close Enough To Those Taught By Carter To Get Substantially The Same Results

The angles called for by the empirical formula of the claims in suit for the wire and wave lengths used by petitioner in its eleven antennae are indicated in the fourth column of the tabulation on the inside back cover of respondent's prior brief. In the third column, the angles actually used by petitioner are shown, the figures having been furnished by petitioner.

From this tabulation it will be seen that *nine of the eleven antennae differ from the angle called for by the empirical formula by less than one half degree* (½°). Petitioner's angles are neither uniformly more nor less than the corresponding angles of the formula, antenna No. 3 having an angle .02° *less,* and antenna No. 5 having an angle .07° *greater* than that called for by the claims. Such slight variations could hardly be avoided in practical field construction. The settling of a pole, or a windstorm could easily produce them. They would be imperceptible except by checking with a surveyor's instrument. They are utterly inconsequential in fact.

By the use of trigonometric tables (to five decimal places) and simple arithmetic, one finds that a variation of .02° in the angle of a V-antenna having wires 441.5* feet long means no more than the shifting of the antenna wires at the outer end of the V *less than two* (2) *inches.* Similarly, a variation of .07° in the angle of a V antenna having wires 565* feet long means no more than that the antenna wires must be moved *less than eight* (8) *inches* at the open end of the V. To carry this variation to its obvious absurdity as a distinguishing difference, if the 10-foot post hole in which the 80-foot poles used for erecting these antennae were *one* (1) *inch out of line from bottom to top of the post hole,* the wire attached to the top of the pole would thereby be thrown more than .07° out of the position it should occupy to be in exact conformity with the formula set out in the claims. *It is therefore apparent that it would be almost impossible to erect an antenna, as a matter of practice, that would conform to the formula with the exactness which this Court has indicated must be secured in order to come within the claims.*

Petitioner's expert Kelley specifically admitted (I, p. 309, in answer to XQ. 1399) that **three of petitioner's antennas are as close to the Carter angle as you can determine by using the curve of Fig. 12 of the patent.**

Petitioner offered no evidence to show how or why it arrived at its angles, and made no claim to any original research in connection with the selection of its angles. Since its antennae were built several months after the publication of Carter's Radio Institute paper, and after respondent had built and publicized its commercial antennae, it is reasonable to conclude, and it has

*These are the lengths of the wires in petitioner's antennas having the variations referred to in this discussion.

not been denied, that petitioner followed the teachings of Carter in determining the angles for its V-antennas.

This Court's opinion says that

> "it is not material that the variations are small between the angles used by petitioner for wire lengths of multiples of quarter wave lengths and those obtained by application of the empirical formula" (page 11, second paragraph).

We assume the Court made this statement because of its belief that Carter's disclosure did not apply at all to wires of odd numbers of quarter wave lengths, rather than because the Court believed that that slight difference of angle *per se* avoided infringement. Otherwise this decision would be furnishing an out for infringement of any patent addressed to a structure defined in terms such as "straight," "square," "circular," "elliptical," "perpendicular," etc. Such a conclusion would be contrary to this Court's decision in *Winans v. Denmead*, 15 How. 330.

In so far as the holding of non-infringement is based on slight and non-functional variation from a claimed structure, the advantages of the patented structure being fully attained in spite of the variation, the Court here ignores the principle laid down in *Sanitary v. Winters*, 280 U. S. 30, 42, that when the substance of an invention is appropriated, infringement will be found even where the exact letter of the claim is avoided.*

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*In the present case, the exact letter of the claim is not avoided because the claims in suit call for "substantially" the angle of the formula.

The Prior Art did not Limit Carter to an Exact Angle

On page 11 of its opinion, this Court indicates that Carter had to define his angle "with mathematical precision" to avoid prior art. But the *only* prior art directive antenna composed of long wires in V formation fed in phase opposition was that described in the second Lindenblad patent. The angle Lindenblad specified for his purposes was less than 12° for wires "five to ten waves long"; admittedly, the Lindenblad antenna did not operate, as Carter's does and as petitioner's do, to secure predominant radiation in the direction of the bisector (see petitioner's Exhibits CC, DD, II, pp. 897, 898).

On this point the trial court found as to the Lindenblad patent:

> "The second Lindenblad Patent 1,927,522.
>
> "This patent is for a traveling wave antenna. No evidence was offered of any adoption or use thereof by anyone. All of defendant's antennas charged to infringe are of the standing wave type. *** This patent is not directed broadly to a V-type antenna as **it is wholly inadequate of disclosure because the proper angle between the antenna [fol. 1369] wires constituting the legs of the V is not given and no means are disclosed by the patent to enable one to determine the proper angle.** Only with proper angles could the stated objects of the patent be attained, that is, that the **main lobe of radiation would be in the plane of the wires and on the bisector of the angle between the legs of the V.**" (II, p. 1149)

> "*No instruction is given in the* [Lindenblad] *specification as to the proper angle, between the legs of the V, and such instruction is necessary be-*

cause without the proper angle, maximum radiation in the direction of the bisector of the angle would not occur, as at certain values of the angle, zero radiation on the line of the bisector is obtained." (II, p. 1150, folio 1370).

And on the same subject, petitioner's expert said:

"Q. 340. Do you find *any instructions in the Lindenblad patent as to the proper angle between the legs of the V antenna shown in Fig.* 2?

"A. *No, I don't.*"

"Q. 341. Do you find in the Lindenblad patent *instructions as to the necessity for or how to obtain the angle between the legs of the V of Fig.* 2 *in order to obtain radiant action predominantly along the direction of the axis of the conductor system?*

"A. *I don't.*" (I, p. 215)

As to Bruce, this Court is simply in error in finding that, prior to Carter, he had plotted a graph "showing the directional radio activity of a V-antenna". Bruce's graph (II, 902) related only to a **single** wire and was **designed to show the angles at which single wires of** different lengths should be **tilted with respect to the ground** to secure maximum response to a horizontally arriving signal. It had nothing to do with a phase-opposition V-antenna. Bruce himself, although a skilled engineer working with several assistants continuously on the problems of short wave directive antennas from 1924 on, did not see any advantage to be gained by application of a preferred angle to antennas of the type here involved, until after the Carter antenna had been invented, set up, and tried out.

Carter was the *first* to teach the art how to construct a V-antenna to secure predominant radiation in

the direction of the bisector. *There was no close prior art requiring Carter to restrict his claims to an exact angle.* Petitioner has followed Carter, not the prior art.

The record shows that **the V angle may be varied as much as 2½° and still get predominant radiation on the bisector twelve times as strong as that of a standard comparison dipole** (Hogan, I, p. 151). The **exact** angle is the **optimum**, but the new result of Carter does not require **exactness**, and infringement is not avoided by slight differences. The **only** angle for a V-antenna given in the prior art was the 12° angle of Lindenblad for **all** wires between five and ten wave lengths long. **That angle is from 20° to 33° off Carter's optimum angle.** But that is the **only** prior art to limit Carter to an exact angle for his V-antenna. **His object of maximum concentration in the direction of the bisector and suppression of useless radiation** is clearly attained by angles having some permissive variation. We submit that the test should be whether the accused device secures the Carter objectives, or only the Lindenblad prior art results.

3. Carter Used the Abraham Mathematics For Theoretical Explanation, But In Addition He Gave Practical Directions Applicable To The Cases Not Treated by Abraham

This Court has treated the Carter disclosure as though it were of no value except in so far as it consisted in applying the old Abraham formula to V-antennae. Since the Abraham formula was worked out with respect to and dealt only with a single wire made up of integral half wave lengths, this Court has assumed that since Carter did not give any mathematical proof of the application of his "empirical formula" to wires of intermediate lengths, he taught nothing with respect to

the use of wire lengths comprising an odd number of quarter wave lengths, such as petitioner uses. So to hold is utterly to ignore the plain wording of the original application, and to fail to see the substance and value of what Carter told the art to do to get the desired results.

The Court has given no weight to the fact that Carter disclosed in his *original* application *three* formulae. The *first* of these, stated, for example, in claims 9, 11, and 13 (not in suit), is applicable to antennae in which the radiating wires are each made up of an *odd* number of half wave lengths. The *second* formula, stated, for example, in claims 10, 12, and 14 (not here in suit), is applicable to antennae in which the radiating wires are each made up of an *even* number of half wave lengths.

But Carter did not stop there, this Court to the contrary notwithstanding. He went on, empirically developed, tested by actual construction and trial of an antenna to which the first two formulas did not apply, and stated in the original application *a third formula giving the optimum relation between wire length, wave length, and angle,* for securing maximum radiation in the direction of the bisector of the angle of a V-antenna,—

> "where the length of wire dealt with does *not* correspond to a whole number of half wave lengths." (Original application, bottom of I, p. 1038).

This Court's opinion seems to assume that because Carter omitted from his specification a mathematical discussion of the law applying to radiation from wires *not* made up of half wave lengths "because of its complexity,"—that therefore the empirical formula of the two claims in suit must be incorrect, or even if correct, that it was not a part of the invention Carter intended to describe. We confess our utter inability to follow the

Court's reasoning on this point. The plain words of the application are directly to the contrary.

4. The Claims Apply To Wires Not Multiples Of Half Wave Lengths, And When So Applied The Same Advantages Are Obtained As Follow Proper Use of Wires That Are Multiples Of Half Wave Lengths

(a) The Court's error in holding that the Carter empirical formula was not intended to apply to anything but wires composed of integral half wave lengths has been discussed above.

(b) Its statement that wires not made up of integral half wave lengths—

> "do not in fact exhibit 'the angle for best directional propagation' "—

follows a finding of the trial court that was clearly erroneous.

The only testimony in the record to the effect that the Carter empirical formula and the curve of Fig. 12 are not accurate when applied to intermediate wire lengths, is that of petitioner's expert Kelley, who merely stated as a *conclusion* that it was not "exact" (I, 238, Q. 440). *He did not give any calculation or figures to show to what extent if any he had found Carter's empirical formula inaccurate in fact.* He never said that it was inaccurate for *practical purposes.* On the contrary, as will be seen from his cross-examination on this point, he was unwilling to state that the extent of alleged inaccuracy was as much as one-tenth of a degree. See XQ. 1469, I, p. 315.

The controlling consideration is that Carter taught the art that maximum radiation could be concentrated in

the direction of the bisector of a V-antenna by proper correlation of the structural elements, and he gave a curve and an empirically arrived-at formula that indisputably are sufficiently accurate for all practical purposes to teach workers in the art how to coordinate the V-antenna elements to get the new result Carter had discovered. That the curve and empirical formula are sufficiently accurate for that purpose is shown by the fact that most of petitioner's antennas have *followed the curve almost exactly* and have obtained the exceedingly valuable results that Carter said would be obtained, *by the coordination taught by Carter's empirical formula.* That would seem to be the real test on this point.

5. Equities And Public Policy Are All In Favor Of Respondent

There is no doubt from the record but that Carter made an important discovery and gave something new and useful to the art. For example, there is no contradiction of any of the following facts:

From 1924 on, many skilled radio engineers were continuously working on the problem of improving short wave directional antennae.

This investigation was carried on continuously not only in this country, but in England, France, and Germany. The Marconi Company arrived in 1926 at a directive antenna that went into world-wide use. Respondent bought and erected two such antennae at a cost of between $100,000 and $175,000 for each. The American Telephone & Telegraph Company after continuously working on this problem through a corps of skilled engineers from 1924 through the times involved

in this case erected in 1929 an antenna of the very costly suspended-curtain type for its short wave transatlantic communication. Respondent itself built and tried out and put into commercial service numerous directive antennae of more expensive and less efficient forms before Carter arrived at the simple and startlingly effective antenna covered by the patent in suit. At a cost of about $5,000 results equal in effective directivity to those of the Marconi antenna were attained, and there were other advantages, such as much lower cost of maintenance, simplicity of adjustment, etc.

After test of Carter's antenna had shown its outstanding advantages (using a 7¾ wave length antenna for that test), *respondent adopted for all further construction of antennae, the Carter structure.* Petitioner, which had previously used other forms of antenna, after respondent had built, used, and publicized the merits of the Carter antenna, itself adopted the V-type antennae. This was because, as its chief engineer said, they were "the most effective" antennae known to him that he could erect for the money he had to spend. (Pratt, I, p. 204).

Petitioner makes no claim whatever to having taken any part in the years of world-wide research with respect to the development of short wave directive antennae, nor to any originality of thought in its own design. Obviously it simply appropriated the results of respondent's research.

Under such circumstances we submit that every inclination of this Court should be to resolve all doubts against petitioner. The public interest is vitally involved in rewarding such a contribution to progress of an art. To do otherwise is to discourage research and invention, and to acquit the commercial trespasser.

6. The Invention Was One of Great Practical Value And The Patent Is Entitled To A Liberal Construction

We respectfully submit that in this case the Court has misunderstood a point which is fundamental in any patent case,—the nature and scope of the invention Carter made. The diagrams in the record illustrate our point.

Figs. 1*a* and 1*b* of the Carter patent (II, p. 492) illustrate the single wire 2-2 discussed by Abraham and the predominant radiation which surrounds it, Y, Y, Y, Y. It will be remembered that this radiation is in hollow cone form, which we have compared in our prior brief, p. 13, to the walls of a megaphone.

Petitioner's Exhibits CC and DD (II, p. 897, 898) illustrate the field of radiation from a Lindenblad V-antenna with the angle given by Lindenblad. The concentration of the radiation is very poor. The maximum concentration is outside the V and goes out in four widely separated directions. Of necessity the great majority of it goes out in unwanted directions and this could not be cured by use of a "reflector" antenna.* That accounts for the fact that the Lindenblad antenna was never used except experimentally. Having tried it out Lindenblad went on to develop other forms of antenna (II, p. 544).

What Carter did was to take the Lindenblad V antenna of the prior art and so correlate the wire length, wave length, and angle that a portion of the cone of radia-

*We here note that Lindenblad did not suggest the use of a "reflector" with his antenna: He proposed to secure unidirective action by the use of traveling waves. This Court was in error in saying (Opinion, p. 3) that,

> "the prior art had made use of an arrangement of wires, parallel to the wires of the angular antenna, as a 'reflector'***."

There is no evidence in the record to that effect.

tion issuing from one of the wires was in line with a corresponding portion of the cone of radiation issuing from the other wire. The remaining portions of the main cones of radiation and all the minor cones would be expected to result in quite large amounts of radiation in random, unwanted, and useless directions. At most one would expect no more than a doubling of the radiation in the desired direction.

But the extraordinary and unexpected result which Carter found by test actually to come about was, we submit, sufficient to lend the utmost dignity to his invention. Instead of having in effect portions of two separate cones of radiation, combining only in the comparatively narrow common area (actually about 10°-20° wide and thick), and therefore merely *adding* the individual radiations that were common in location and direction, **Carter found that the result was quite different from what was to be expected. Unpredictably the proper V-arrangement cancels most of the radiation except that issuing in the direction including the superposed portions of the cones.** Substantially all of the energy radiated in the directions of the other portions of the two main cones, and also in the directions of the minor cones (which energy one would expect to be wasted from a practical point of view), appeared as energy in the desired direction. See Hogan, I, p. 122. The resulting horizontal distribution of radiation is shown in Fig. 3 of the Carter patent (II, p. 494).

The advance made by Carter over Lindenblad is shown to scale, in respondent's Exhibit 53. The Lindenblad radiation in the horizontal plane of the wires is shown at II, p. 720; and that of Carter for like wave and wire lengths at II, p. 722. The same respective results in the vertical plane of the bisector are shown for

Lindenblad at II, p. 721, and for Carter at II, p. 723.

Nothing in Abraham or Lindenblad's work taught that such a result would follow such an arrangement. No one had ever proportioned a V-antenna to get that result before Carter, or foreseen or suggested that such a result might follow. Carter determined it by actual test, getting results that could not have been predicted by any process of "logical application of known scientific law," and not taught directly or indirectly by Abraham. The astonishing results of Carter's tests of his antenna, made and reported in detail before he filed his application for patent, are shown by his report to his engineering superior. See II, pp. 699-708, particularly page 702.

We submit that such a discovery and its practical application constitute an invention entitled to liberal treatment and that the Court was in error in regarding the invention as a narrow one, and the patent as one to be strictly construed and only infringed by precise copying of a specific example. It is entitled to a construction sufficiently broad to include anything which by substantially the means specified secures the new result which Carter discovered, a result far superior to the results obtainable with the prior art arrangements.

Respondent should be given opportunity to make clear to the Court the errors in its decision.

Respectfully submitted,

Jo. Baily Brown,

Abel E. Blackmar, Jr.,

Counsel for Respondent.

February 20, 1939.

APPENDIX A

As to Certain Scientific Misconceptions In This Court's Opinion

We have studied this Court's opinion at length in an effort to determine the basis for its failure to give effect to the plain statement in the Carter application that his invention was applicable "where the length of wire dealt with does *not* correspond to a whole number of half wave lengths." We have found a number of scientific errors or apparent misapprehensions which may have led to the decision. At the risk of being unduly abstruse, we wish to call these matters to the Court's attention.

(1) In foot-note No. 1 (page 4 of the opinion), it is stated:

> "When the length of the wire is a multiple of half wave lengths, the oncoming and reflected waves, traveling at the same velocity, occur simultaneously, *differing in this respect* from the waves in a wire of a length intermediate a multiple of half wave lengths, and *with different effects upon the resulting radio energy,* presently to be noted."

This statement indicates to us that this Court thinks that true, symmetrical, standing waves are not present on an antenna wire that is, for example, an odd number of quarter waves long. Such a misconception is easy to understand for it might seem that, with waves of such length, the oncoming and reflected waves do not "occur simultaneously" and would be "jumbled up" and could not exist in symmetrical form. Possibly this might be so were it not for the fact that the two wires which constitute the V antenna are in all cases *tuned,* as by the U loop referred to by Carter or by equivalent means. As Carter states (patent, II, 501, lines 11-16):

> "*For best tuning*, the total *over-all* length of both of the wires *and* the U loop terminating them should be effectively an *integral number of half wave lengths*, although the portion forming the radiation element can be of *any* length."

Thus the antenna, as a whole, is, effectively (*i.e.*, electrically), a multiple of half wave lengths long regardless of the length of the radiating wires. As Hogan said (I, 112, Q. 58) the type of antennae that we have in this case

> "are *tuned* so that the waves *build up in the standing wave form.*"

And, referring specifically to petitioner's antenna No. 2, the antenna wires of which were 7.74 wave lengths long, Hogan pointed out that the antenna

> "was *tuned* and adjusted by means of the U-shaped loop, extending from MN to the antenna point CD, ***" (I, 139)

and also (I, 137) that this antenna has "the desired standing waves."

And petitioner's expert Kelley said (I, 215) that petitioner's antennae are of the *standing wave type* and (I, 210) that

> "An antenna of the standing wave type by its very nature should be *tuned* for best operation."

Furthermore, *petitioner's* Exhibits Y and Z (II, 822, 823) show that this Court was incorrect in stating that there are "different effects upon the resulting radio energy" in the case of odd quarter wave length wires.* Exhibit Z also shows that Carter's empirical formula is

*The minor lobes have a somewhat different form, but that is of no importance here. Kelley admitted (I, 316, XQ. 1477) that the main lobes "are pretty near the same" in magnitude.

correct for a wire 7¾ wave lengths long. The formula shows an angle of 17.8° between the predominant direction of radio activity and the wire (I, 139): *Petitioner's Exhibit* Z *shows the same angle* so far as can be determined therefrom. (See Kelley's testimony at I, 317-8, XQs. 1493-6.)

Petitioner has always contended that all of its antennae are of the true standing wave type. The Trial Court found as a fact that they are. See II, p. 1149.

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(2) This Court states (opinion, p. 8) that wires not multiples of half wave lengths

> "do not in fact exhibit 'the angle for the best directional propagation.'"

Again—

> "It [Carter's empirical formula] reveals no scientific law applicable to wire lengths which are intermediate of multiples of half wave lengths, ***."

And again (pp. 8-9)—

> "Neither the empirical formula nor its graph gives any clue to the directional radio activity resulting from the use of wire lengths intermediate of multiples of half wave lengths, ***."

We believe that the record shows that this Court has here fallen into scientific error. We have pointed out above that *petitioner's* Exhibit Z shows that the empirical formula states the angle between the main lobe of radiation and the wire correctly. *Petitioner's* evidence also shows that structures having wires of lengths intermediate of multiples of half wave lengths *do* in fact "exhibit 'the angle for the best directional propagation'" and that the empirical formula and the graph of Fig. 12

not only give a "clue to the directional radio activity resulting from the use" of such intermediate wire lengths but *give all the information as to that subject that is necessary to build an antenna which utilizes the best angle between the wires.*

Thus Kelley testified (I, 243) that

> "The result of this is that *better* directivity results by *departing from an integral number of half wave lengths,* and going to an odd number of quarter wave lengths,"

and explained that this is due to there being a smaller amount of energy in the *minor* lobes in the latter case. **And petitioner's use, for an antenna having wires 7.69 wave lengths long, of an angle differing from Carter's by only 0.02° shows that Carter gave all the information that was necessary to construct a directional antenna using wires of such length.** As we have pointed out above (p. 17), 0.02° difference, in the case of a wire 441.5 feet long, means a displacement, at the end of the wire, of *less than* 2 *inches,*—a displacement which might be caused by wind pressure on the wire or the pole or by negligible settlement of the pole.

Suppose there were no logical, scientific justification for Carter's method of deriving his empirical formula, what difference can that make so long as the formula, when derived, was accurate for all practical purposes and was sufficient (when taken with Carter's specification) to instruct one skilled in the art to construct an antenna with all the advantages claimed by Carter? Why is it "legerdemain" to say that Carter's invention included a structure described and claimed by him, even if the formula defining that structure had been developed on a basis not mathematically explained in detail?

(3) This Court states (opinion, p. 9) that the empirical formula "had been devised as a shorthand expression" of the Abraham law and that use of it in connection with wires intermediate in length between multiples of half wave lengths was a use,—

"for a purpose for which it was not devised***."

These statements disregard the plain statement of the application as filed that the formula is applicable "where the length of wire dealt with does not correspond to a whole number of half wave lengths." As this statement was a part of the application, it must be given effect. The Court is plainly in error in its conclusion.

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(4) Referring to the first two paragraphs of page 10 of the opinion, the amendments to the application did not in any way affect the reference to the Abraham law nor "modify the Abraham formula." That law still stands, in the patent, as an explanation of the radiant action where the wires are an *integral* number of half wave lengths long; the claims embodying the Abraham formulas (Nos. 9-14) are still for antennae with wires an odd or even number of half waves long; and the letter n of the Abraham formula is still "the number of half wave lengths contained in the wire." The amendment defining the terms "plurality of wave lengths," or "plurality of half wave lengths," or "several half wave lengths" (II, 502, lines 35-42) *does not apply to any of the claims embodying either the Abraham or the empirical formula;* it applies only to claims (such as claim 1) that embody one or the other of those terms.

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(5) At pages 10-11 of its opinion, this Court says:

"*The testimony warrants the conclusion* that differ-

ences in wave effect already noted, when wires of other than exact multiples of half wave lengths are used, produce, through consequent changes in 'radiation resistance,' *differences in the angle* of directional radio activity not calculable by the formulae of the patent. It establishes that they *do not give the angle 'for the best directional propagation'* for structures using this intermediate range of wire lengths, ***."

This is correct in so far as it applies to the *Abraham* formulae. But applied to the empirical formula, the testimony shows that it is not correct. The only testimony that might be thought to support the conclusions of this Court and the trial court on the point is Kelley's categorical answers to Q. 440 (I, 238) and to XQs. 1457-8 (I, 314-5). The remainder of his testimony, however, does not support these answers.

As to his direct examination, he said (I, 239) that the inaccuracy of the empirical formula would be "indirectly" shown by the radiation resistance curves. He then discussed such curves (I, 239-244, Qs. 442-455) but *never once asserted that they had anything to do with the ANGLE of radiation;* instead, he merely showed that there was less radiation in *undesired* directions when the wires were other than multiples of half wave lengths long.

His cross-examination on this point is at I, 315-318 (XQs. 1459-1496). He again referred to radiation resistance curves, but only to show that "it would not be safe to assume" that the empirical formula was correct (XQs. 1459-1460). As to the extent of supposed error in the empirical formula, Kelley here testified:

"XQ. 1462. Can you tell me by how much the angle departs from the correct angle at a point say

between six and one-half and seven wave lengths?

"A. *No, I do not recall how much.* At some point *they are calculated* and there is a difference.

"XQ. 1463. And what is the order of the difference?

"A. I don't remember that, *it is not a large amount,* I can tell you that.

"XQ. 1469. It might or might not be *one-tenth of a degree?*

"A. Well, *that I don't remember also.*"

And note that he *never produced the calculations* which would show the supposed difference.

We have pointed out elsewhere the affirmative evidence that the empirical formula *does* "give the angle 'for the best directional propagation' for structures using this intermediate range of wire lengths."

We therefore submit that the finding of this Court to the effect that it does not is clearly erroneous and is contrary to the evidence.

APPENDIX B

Sec. 4888. (U. S. C., title 35, sec. 33.). Before any inventor or discoverer shall receive a patent for his invention or discovery, he shall make application therefor, in writing, to the Commissioner of Patents, and shall file in the Patent Office a written description of the same, and of the manner and process of making constructing, compounding, and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art or science to which it appertains, or with which it is most nearly connected, to make, construct, compound, and use the same; and in case of a machine, he shall explain the principle thereof, and the best mode in which he has contemplated applying that principle, so as to distinguish it from other inventions; and he shall particularly point out and distinctly claim the part, improvement, or combination which he claims as his invention or discovery. The specification and claim shall be signed by the inventor. No plant patent shall be declared invalid on the ground of noncompliance with this section if the description is made as complete as is reasonably possible.

pp. 8+11,

SUPREME COURT OF THE UNITED STATES.

No. 127.—October Term, 1938.

Mackay Radio and Telegraph Company, Inc., Petitioner, *vs.* Radio Corporation of America.	On Writ of Certiorari to the United States Circuit Court of Appeals for the Second Circuit.

[January 30, 1939.]

Mr. Justice Stone delivered the opinion of the Court.

The questions presented for decision by the petition for certiorari are whether the Carter patent, No. 1,974,387, of September 18, 1934, for a directive antenna system for use in radio communication, is valid and is infringed by antennae structures used by petitioner in such communication.

Respondent brought the present suit in the District Court for eastern New York to enjoin infringements of four patents relating to radio antennae or their operation. Two were those of Carter and two those of Lindenblad. Of these only the second Lindenblad patent, No. 1,927,522, of September 19, 1933, for an antenna for radio communication, is of present importance. When the suit was begun the application for the third Carter patent, with which we are presently concerned, was pending. After petitioner had answered and respondent, as a result of the litigation, had acquired knowledge of the particulars of the structure and operation of petitioner's antennae, Carter, respondent's assignor, amended the statement of his invention in his application so as in terms to embrace a differentiating feature of petitioner's structures. After this patent was issued respondent was permitted to file a supplemental bill charging infringement of it. The suits were consolidated, and the parties proceeded to trial on the issues of the validity and infringement of all five patents.

After taking the voluminous testimony of numerous witnesses, the trial court found that none of the patents in suit was infringed and decreed that the suits be dismissed. 16 F. Supp. 610. It held that none of them was a pioneer patent; that none had been employed by any one; that respondent's commercial structures did not follow the teachings of any of them; and that consequently

they were not entitled to a broad construction. With respect to the Carter patent in suit it said: "The disclosure and the claims were broadened not only contrary to their original terminology but to their spirit as well." And " . . . by those amendments the plaintiff attempted to mold the third Carter patent both as to disclosure and claims, to cover defendant's antenna systems. This could not lawfully be done."

On appeal from so much of the decree as related to the second Lindenblad patent and the third Carter patent, the Court of Appeals for the Second Circuit affirmed as to the Lindenblad patent, but reversed as to the Carter patent, holding Claims 15 and 16 valid and infringed. 96 F. (2d) 587. We granted certiorari, — U. S. —, because of the nature and importance of the case, on a petition which urged as grounds for its allowance that validity and infringement of the Carter patent were in doubt and that, as petitioner is the only competitor of respondent in the business of world wide public radio communication, further litigation, resulting in conflict of decision among circuits, was improbable.

In ordinary broadcasting, radio waves are projected in all directions from the sending station. In radio communication it is advantageous and has long been the practice to use a directive antenna by which the waves of radio activity emanating from it are projected as a beam in the direction of the receiving station. In practice the beam is directed at an angle from the earth's surface toward the ionized layer of the stratosphere, or Heaviside layer, from which the beam is deflected toward the earth's surface in the compass direction of the receiving station. In more recent years it has been the practice to use relatively short wave lengths for radio communication.

The radio waves are generated at the sending station by feeding an oscillating electric current of appropriate character into the wire or wires of the antenna. The electric waves in the wires energize radio activity, which the antenna projects as radio waves toward the receiving station. By modulating or interrupting the current, corresponding modulation or interruption of the radio waves is effected, which may be used as a means of transmitting any desired signal. The waves, as modulated, impinge on the antenna of the receiving station devised to receive and utilize them as a means of controlling, with corresponding modulation, an electric current which in turn actuates a mechanism contrived to give audible or visual expression to the transmitted signal.

The effective part of the antenna is a copper wire from which the radio waves are radiated, supported on towers or poles at a height above the ground depending on the wave length used. The wire may be parallel with the earth, or vertical, or arranged at an angle, depending upon the function to be performed. Before Carter, antennae of two or more wires in varying arrangement had been used. The second Lindenblad patent showed an antenna of two wires arranged at an angle in the form of a V or an X, and it pointed out that in such an arrangement radiation will take place in the direction of the axis or bisector of the angle of the diverging wires, and that "the spacing at the open end [of the wires], while variable over a great range, should be in the neighborhood of a fifth of the length, and the length of each antenna section should be of the order of magnitude of five to ten waves long."

While such an arrangement projects the radio waves principally in two directions along the bisector of the angle of the antenna wires, the prior art had made use of an arrangement of wires, parallel to the wires of the angular antenna, as a "reflector" by which the radiation was projected as a beam in one direction away from the reflector and along the bisector of the angle of the wires.

The present Carter patent is for an "antenna system utilizing standing wave phenomena." Like the second Lindenblad patent, it is concerned with a V antenna by which the principal radiation is directed in the plane of the wires along the bisector of their angle. The disclosure of the patent, in which the court below found invention, was that the best directional radio propagation by the V type antenna is obtained with a structure in which the angle of the wires, their length, and the length of wave propagated are in a definite mathematical relationship expressed by a formula disclosed in the specifications.

In explaining his invention, Carter pointed out that "It is known that when a wire having a length greater than the operating wave length is excited in such manner that standing waves are produced thereon, radiation will occur principally in the direction of symmetrical cones having their apices at the center of the wire. Such is the case with a wire having a length equal to a plurality of one-half wave lengths at the operating frequency. The radiation pattern produced in such instance appears, in cross section, in the form of symmetrical cones about the wire. The present invention, which makes use of these phenomena, in its most simple aspect employs a pair of open-ended wires energized in phase op-

position to have standing waves throughout the length of the wires, the wires having such angular relation with respect to each other as to obtain a highly directional, efficient and simple antenna system."[1]

The patent states the mathematical formula by which the desired relationship is secured, which shows that the appropriate angle between each of the antenna wires and their bisector depends upon the wave length to be propagated and the use of antenna wires of a length which is a multiple of half wave lengths.[2]

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[1] Understanding of the disclosure and other features of the patent requires a brief explanation of its terms. The term "long", as applied to an antenna, means a wire which is long in relation to the wave length used. The term "standing waves", as distinguished from "traveling waves", describes the phenomenon manifested when an oscillating electric current of radio frequency is communicated to one end of a wire which is open at the other (that is, not in a closed circuit) and sufficiently short so that the waves have not completely radiated their energy before reaching the end of the wire. The waves will then be reflected back along the wire, and the energy of the reflected waves tends to unite with that of the oncoming waves of the same periodicity, so as to produce standing waves along the wire. As the velocity of the radio wave in space is approximately that of the current waves in the wire, the number of complete standing waves on the wire is always exactly the same as the length of the wire divided by the wave length. When the length of the wire is a multiple of half wave lengths, the oncoming and reflected waves, traveling at the same velocity, occur simultaneously, differing in this respect from the waves in a wire of a length intermediate a multiple of half wave lengths, and with different effects upon the resulting radio energy, presently to be noted.

When oscillating current is so related to the length of wire that the energy of the former is exhausted by radiation before or when the waves reach the end of the wire, there is no reflection of the waves, and they travel in one direction only toward the open end of the wire. They are denominated "traveling waves". In professional parlance, wires producing reflected, and hence "standing" waves, are electrically of finite length. Those of sufficient length to avoid reflection and thus carry waves flowing in only one direction are said to be electrically of infinite length.

[2] The specifications state: "By considering a long wire the equivalent of a very large number of very short, (Hertz) oscillators and by adding up the field components at any point P having a direction angle θ relative to the axis of the wire, where the point P is a great distance from the wire as compared to the length of the wire such that all lines from point P to any point on the wire are essentially parallel, it can be shown that the field strength H is given by the following proportionality for a conductor an odd number of half wave lengths long:

$$H \propto \frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

The letter "n" indicates the number of half wave lengths contained in the wire.

For a wire an even number of half wave lengths long, in similar fashion, the field strength "H" is given by the following proportionality:

$$H \propto \frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}$$

Where n as above indicates the number of half wave lengths on the wire."

The significance of the formula lies in the fact that the angle between the wire and the direction of greatest radio activity is a trigonometrical function of two variables, the wave length used and the "number of half wave lengths contained in the wire", and that, as the application stated, the use of the formula in practice presupposes the use of a wire whose length is a multiple of half wave lengths. The patent then explains that the angle θ of the formula is the angle between each wire of the V antenna and its bisector—in other words, that the angle of the wires of the antenna is twice θ and hence, like the angle of the formula, is a function of the wave length and the length of the wires, which are each a multiple of half wave lengths long.

Carter did not invent the formula. It had been developed by Abraham and published in a scientific journal thirty years before. Annalen der Physik, 1898, Physikalische Zeitschrift, March 2, 1901. Abraham's formula expressed the scientific truth that when radio activity is projected from a charged wire of finite length, i.e., one having standing waves, and having a length of a multiple of half wave lengths, the angle between the direction of the principal radio activity and the wire is dependent on wave length and wire length, which is a multiple of half wave lengths. Lindenblad had described his antenna as using either standing or traveling waves and, as we have seen, had taught that with an arrangement of antenna wires at an angle, radiation will occur substantially in the direction of the bisector of the angle and that the preferred angle was dependent upon an indicated relationship between wire length and wave length.

It is plain, therefore, that the Carter invention, if it was invention, consisted in taking the angle of the Abraham formula as the angle between each wire of the V antenna and its bisector. By so doing he brought the cones of principal radio activity, each having one of the wires of the antenna as its axis, into conjunction at their periphery and along the bisector of the angle between the wires, and thus established there the greatest directional radio activity.

While a scientific truth, or the mathematical expression of it, is not patentable invention, a novel and useful structure created with the aid of knowledge of scientific truth may be. But we do not stop to solve the problem whether it was more than the skill of the art to combine the teaching of Abraham with that of Lindenblad and others who had pointed out that the arrangement of the wires at an angle enhanced directional radio activity along their bisector. We assume, without deciding the point, that this

advance was invention even though it was achieved by the logical application of a known scientific law to a familiar type of antenna. But it is apparent that if this assumption is correct the invention was a narrow one, consisting of a structure conforming to the teachings of the Abraham formula as to angle and wire length relative to wave length, and is to be strictly construed with regard both to prior art and to alleged infringing devices. *Kokomo Fence Machine Co.* v. *Kitselman,* 189 U. S. 8; *Cimiotti Unhairing Co.* v. *American Fur Refining Co.,* 198 U. S. 399. Carter's structure was a V antenna having an angle double the Abraham angle and wires containing a multiple of half wave lengths.

Carter, using the Abraham formula, calculated the value of the angle θ in that formula for wires up to fourteen wave lengths long. He plotted the result, which he expressed graphically in figure 12 of the patent by drawing a smooth curve connecting the discrete points on the graph which indicated the results of his computation by use of the Abraham formula. From this calculation he derived a formula in empirical form[3] for determining the desired angle when wave length and length of wire are known, in which the angle between the wires is described as twice α, which is the equivalent of the angle θ of the Abraham formula.

Petitioner uses antennae with wires in V arrangement, but their wires are not an integral number of half wave lengths long, with the exception of one antenna, No. 8, which is four wave lengths long and uses an angle 10% smaller than that prescribed by the Abraham formula for that length of wire. The others are of lengths which are approximately multiples of quarter wave lengths, and their angles differ from the angles of the formula. The crucial question in the case is whether a V antenna structure, having a wire length to which the Abraham formula does not apply and using an angle not to be derived from that formula, which is the basis of the patent, infringes Carter's patent. Respondent insists that it does, because, as it argues, the invention disclosed by Carter's application, elaborated by amendment and broad claims, embraces all V antennae arranged at an angle double the angle of the empirical formula, even though the length of the wires is not an exact multiple of half wave lengths, as prescribed by the Abraham form-

[3] "For practical purposes the empirical formula

$$\alpha = 50.9\left(\frac{l}{\lambda}\right)^{-0.38} \text{ degrees}$$

is sufficiently accurate where l equals the length of the wire and λ the wave length, both in the same units of measurement."

ula. This is the invention of Claim 15,[4] and it is urged that the claim is amply supported by the statement in the specifications appearing in the original application that the empirical formula represented by the plotted curve of figure 12 of the patent "will be found accurate for all practical purposes where the length of wire dealt with does not correspond to a whole number of half wave lengths."

The trial court, analyzing Carter's application and taking into account the essentials of the Abraham formula and the statement in the application that the "object of the present invention is to disclose the proper angle for conductors or radiators" measured in multiples of half wave lengths, evidently thought, as petitioner argues, that the references in the application to "wires of finite"[5] length and to wires "of any length whatsoever"[6] were intended only to refer to wires of electrically finite as distinguished from electrically infinite length, capable of producing standing waves utilized by the antenna of the patent, and of any length conforming to the requirements of the basic formula.[7] It concluded that the cor-

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4 "15. An antenna comprising a pair of relatively long conductors disposed with respect to each other at an angle substantially equal to twice

$$50.9\left(\frac{l}{\lambda}\right)^{-0.23}$$

degrees, l being the length of the wire and λ the operating wave length in like units, and means in circuit with said antenna for exciting the conductors in phase opposition whereby standing waves of opposite instantaneous polarity are formed on the conductors throughout their length."

Claim 16 claims an antenna arranged in conformity to the empirical formula, as in Claim 15, with "a similar parallel pair of conductors spaced an odd number of quarter wave lengths away from said first mentioned pair . . ." These parallel wires constitute the "reflector", which, as already noted, was old in the art.

5 "Still a further object of the present invention is to disclose the proper angle for conductors or radiators either an even number of half wave lengths long or an odd number of half wave lengths long, and, in general to disclose the angle for best directional propagation for wires of any finite length."

After the present suit was brought this paragraph was amended to read:

"Another object of the invention is to disclose the angle for the best directional propagation for open-ended wires of any finite length, preferably longer than the operating wave length, having standing waves thereon and arranged in the manner proposed."

6 "Moreover, it should be clearly understood that the wires of each unit can be of any length whatsoever provided they are placed at the correct angle for their length. For best tuning, the total over-all length of both of the wires and the 'U' loop terminating them should be effectively an integral number of half wave lengths, but, the portion forming the radiation element can be of any length. The law, giving the correct angle for lengths between odd and even number of half wave lengths, is not given due to its complexity but, the empirical formula and the curve of figure 12 will be found accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths."

7 See note 1, *supra*.

rect construction of the application was that the invention described did not go beyond the scope of the Abraham formula and so extended only to the angles calculable by that formula for standing wave wires measured by multiples of half wave lengths. Support is given to this conclusion by the statement in the application that "The law, giving the correct angle for lengths between odd and even number of half wave lengths, is not given due to its complexity . . ."

The Court of Appeals placed emphasis on the reference to "wires of any finite length" and on the statement that "the empirical formula and the curve of figure 12 will be found accurate for all practical purposes, where the length of wire dealt with does not correspond to a whole number of half wave lengths." It held that the invention disclosed was the application of the empirical formula to all lengths of antenna wires and embraced all angles resulting from such calculation, and that the invention was consequently infringed by petitioner's structures.

Whether or not it was the purpose of the patentee, by these references to wire lengths in his application, to extend his patent to structures not conforming to the Abraham formula, we are not able to construe the application, before amendment at least, as embracing such an extension. And we think that the attempt to extend the claims, based on the application of the empirical formula, to wire lengths not multiples of half wave lengths, must fail, ~~both~~ because such structures are not within the invention described in the application ~~and because structures having wires of that length do not in fact exhibit "the angle for the best directional propagation"~~.

The formula in Claims 15 and 16 is the empirical formula derived from the Abraham formula, which is, by its terms, applicable only to antenna wires which are multiples of half wave lengths long. Carter's empirical formula, wholly derived from Abraham's formula, and taken together with it, therefore discloses no invention or discovery more than the application of the Abraham formula to the V antenna. It reveals no scientific law applicable to wire lengths which are intermediate of multiples of half wave lengths, and the application explicitly states that "the law, giving the correct angle for lengths between odd and even number of half wave lengths, is not given". The preparation, by methods familiar to engineers, of the graph in figure 12, which was but a pictorial representation of the Abraham formula applied to certain wire lengths specified in the formula, did not involve invention. Neither the empirical

formula nor its graph gives any clue to the directional radio activity resulting from the use of wire le. ·ths intermediate of multiples of half wave lengths, which were excluded by the Abraham formula, and neither afforded any basis for a claim of invention not supported by the use of the Abraham formula itself.

The claimed use of the empirical formula for the calculation of the angle for wires which are not multiples of half wave lengths long thus involved a departure from what Carter's application had described as his invention, and a contradiction of it. What Carter did was to describe his structure in terms of its dimensions, arrived at by the use of the Abraham formula, which was stated to embody the applicable scientific law. He then derived the empirical formula from Abraham. From the very method of derivation the empirical formula meant nothing different from that of Abraham. He then declared the empirical formula to embody a method of arriving at the measurements of a structure different from the structure first described as the invention and not capable of construction by the method of the Abraham formula. If, as a result of this legerdemain, a V antenna having wire lengths a multiple of any fractional wave length is to be taken as the invention of Carter's application, then everything that it said of the Abraham formula and of wires "either an even number of half wave lengths long or an odd number of half wave lengths long" could be discarded without changing its meaning.[8]

This attempt to broaden the only invention described in the application through a purely mechanical alteration of the meaning of the empirical formula, which had been devised as a shorthand expression of the scientific law on which the invention was declared to rest, cannot, we think, be taken to enlarge the description of the invention as measured by the Abraham formula, so as to include a structure to which that formula does not apply. This use of the empirical formula for a purpose for which it was not devised does not justify our construing the application as though all reference to the Abraham formula had been eliminated and a new and different one expressing a new and different scientific law had been substituted for it. The result of reading the application as respondent contends it should be construed is precisely the same as though full effect were given to a claim which goes beyond the invention described, and it is open to the same objection.

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[8] See note 5, *supra*.

After the present suit was brought the application was altered by amendment so as in effect to wipe out all reference to the scientific law by which Carter's invention was defined. This was accomplished by changes which implicitly assert that the letter *n* of the formula of the invention, the Abraham formula, meant something different from "the number of half wave lengths contained in the wire" of a length of multiples of half wave lengths as stated both in the application and in the patent.

The reference in the application to the purpose of the invention to disclose the "proper angle" for radiators of multiples of half wave lengths long was altered by eliminating from it all mention of half wave lengths.[9] A sentence added after formal allowance of the patent states: "By the term 'plurality of wave lengths' or 'plurality of half wave lengths' or 'several half wave lengths' it is not intended that the wires so described shall necessarily be an exact or approximate integral number of such lengths, unless so specified, but rather that each of the wires so described shall be sufficiently long to include the lengths specified." These amendments operated to modify the Abraham formula so as to cancel from the application the statement of the scientific law defining the invention. They left as its definition the modified Abraham formula and its counterpart, the empirical formula, stating a different law which their genesis did not authorize.

We think that these alterations were not permissible. *Schriber-Schroth Co.* v. *Cleveland Trust Co.*, 305 U. S. —, and that without them the invention must be taken to be limited to a structure having an angle double that disclosed by the Abraham formula, which was made the basis of the alleged invention. As already shown, neither the Abraham formula nor the empirical formula describes, or purports to describe, the directional radio activity or defines the angle which affords "the best directional propagation" of the patent for antennae of wire lengths intermediate of multiples of half wave lengths. The expert testimony shows that in fact neither formula serves that purpose. The finding of the trial court that they do not make "a correct showing of what happens when the wires are other than exact multiples of half wave lengths" is supported by the evidence. The testimony warrants the conclusion that differences in wave effect already noted,[10] when wires

[9] See note 5, *supra.*

[10] See note 1, *supra.*

of other than exact multiples of half wave lengths are used, produce, through consequent changes in "radiation resistance", differences in ~~the angle of~~ directional radio activity not calculable by the formulae of the patent. ~~It establishes that they do not give the angle "for the best directional propagation" for structures using this intermediate range of wire lengths, and that the claimed structures embodying that range of wire lengths defined by use of the empirical formula are therefore invalid~~. It follows that Claims 15 and 16, so far as they claim antennae of wire lengths intermediate of multiples of half wave lengths, are invalid. So far as the patent discloses and claims invention of a structure made in conformity to the Abraham formula, petitioner's structures do not infringe, for none of them conforms to the Abraham formula.

For reasons already indicated it is not material that the variations are small between the angles used by petitioner for wire lengths of multiples of quarter wave lengths and those obtained by application of the empirical formula. Further, Carter's advance over prior art was in specifying an exact angle for wires of the prescribed length. Lindenblad had indicated a preferred angle, and Bruce, before Carter, had plotted a rule of thumb graph, which the trial court found to be prior art, showing the directional radio activity of a V antenna and exhibiting relatively small variations from that of Carter. Carter, avoiding prior art by defining his angle for antennae with wires of particular wave lengths with mathematical precision, cannot discard that precision to establish infringement. *Kokomo Fence Machine Co.* v. *Kitselman, supra; Cimiotti Unhairing Co.* v. *American Fur Refining Co., supra,* cf. *General Electric Co.* v. *Wabash Corp.*, 304 U. S. 364.

It is unnecessary to discuss the further question whether petitioner's structures avoid infringement because the direction of their principal radio activity is not in the plane of the wires, an operative difference from the antennae described by the patent which the court below found to be due wholly to ground effect, which it thought must be assumed to be envisaged by, though not stated in, the Carter patent.

Reversed.

Mr. Justice ROBERTS took no part in the consideration or decision of this case.